INVENTORY OF PLEISTOCENE-HOLOCENE DEPOSITS

OF THE BEAR RIVER RANGE

LOGAN RANGER DISTRICT, WASATCH NATIONAL FOREST, UTAH

FINAL REPORT

Jerome V. DeGraff

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ABSTRACT

The Bear River Range, in north-central Utah, contains a variety of geomorphic elements. Geologic events and setting have influenced the formation of these elements. Controlling factors of the geologic setting include: Paleozoic-age bedrock composed predominantly of carbonates, synclinal and anticlinal structures within the mountain range, and an adjacent graben valley. Geologic events contributing to geomorphic development include: (?) Bull Lake and Pinedale glaciations, various levels of Lake Bonneville, and Hypsithermal climatic conditions.

Geomorphic elements within the Bear River Range result from mass movements, or periglacial, or fluvial processes. These elements are found in some of the eighteen canyons draining the western half of the mountain range. In sequence from north to south, the canyons are: High Creek, Oxkiller Hollow, Cherry Creek, City Creek, Nebo Creek, Smithfield, Birch, Dry (North), Hyde Park, Green, Logan, Dry (South), Providence, Millville, Blacksmith Fork, Hyrum, Paradise Dry, and East canyons.

Mass movements in the study area are commonly old, inactive features. Only a few sites are recent in age, or currently active. Slopes with a west aspect or a west-component aspect are more prone to movement than other slope aspects. The most frequently disturbed lithology is weathered Tertiary formations which are often conglomeratic. A wide range of slope inclinations have landslides.

Alluvial fans have formed at the mouths of many tributary canyons. Based on degree of soil development and relations to features of known age, a sequence of fan development is recognized. Alluvial fans formed prior to Wisconsinan

time and repeatedly thereafter during interglacial periods. Many of the fans formed after the Pleistocene under favorable conditions that existed during periods in Holocene. A large number of fans are related to the Hypsithermal time.

Periglacial action has produced a distinctive element called patterned-diamicton fields. Patterned-diamicton fields are widely distributed within the range. There is no consistent relationship to exposed lithologies or physical setting. The apparent relationship of slope aspect, elevation, and solar radiation suggests an origin by temperature-dependant process, for near-identical temperatures were calculated for all patterned-diamicton field sites. Based, in part, on a reconstruction of Pleistocene temperatures, the patterned-diamicton fields are probably a form of patterned ground resulting from frost action during glacial episodes.

INTRODUCTION

General Statement

The Bear River Range, north-central Utah, and the eastern margin of Cache Valley, Utah comprise the 1,120 square miles under investigation. Previous workers have restricted their geomorphic studies to selected areas or to certain processes and features.

The major geomorphic elements identified in this investigation are compiled on a map with a topographic base (Plate 1). Geomorphic processes responsible for these elements are analysed. A synthesis of factors relating to site selection outlines considerations based on these elements and processes.

Location and Accessibility

The study area is in the north-central part of Utah (Fig. 1). The location falls within the Middle Rocky Mountain physiographic province near the western boundary between it and the Basin and Range province (Raisz, 1952). The main physical features within the area are the western part of the southern part of the Bear River Range and the adjacent southern part of Cache Valley. The study area lies between 111°30'00" to 111°52'30" West longitude and 42°00'00" to 41°30'00" North latitude. It includes all of the following 7.5-minute topographic maps: Tony Grove Creek, Temple Peak, Boulder Mountain, Hardware Ranch, Naomi Peak, Mt. Elmer, Logan Peak, and Porcupine Reservoir (Fig. 2). Additionally, the eastern part of the following 7.5-minute topographic quadrangle maps are included: Richmond, Smithfield, Logan, and Paradise (Fig. 2).

U.S. Highway 89 and 91, State Highways 61, 101, 163, 170, and 217, county roads, and town streets provide complete vehicular access to Cache Valley. The

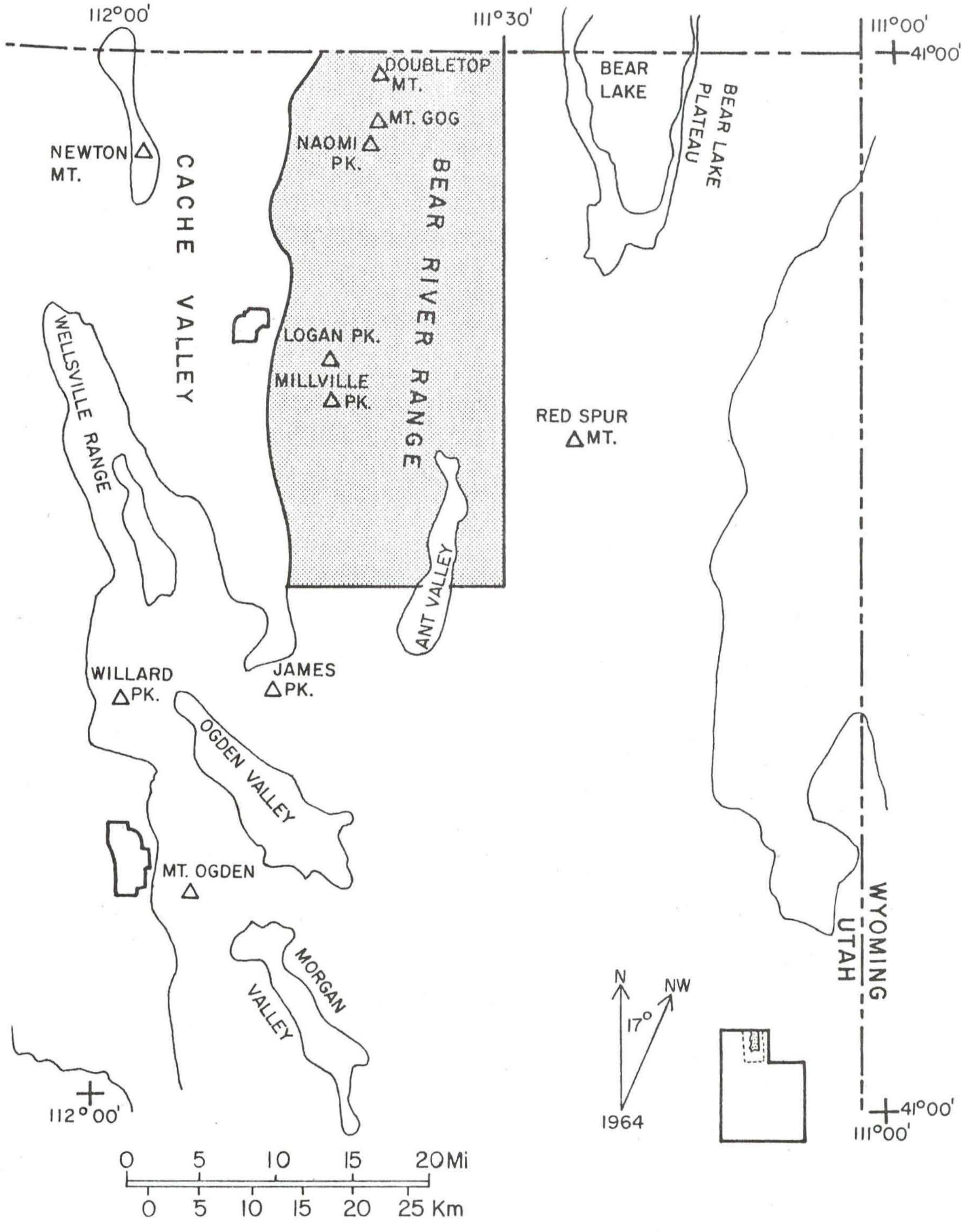

Figure 1. Index map showing location of the study area.

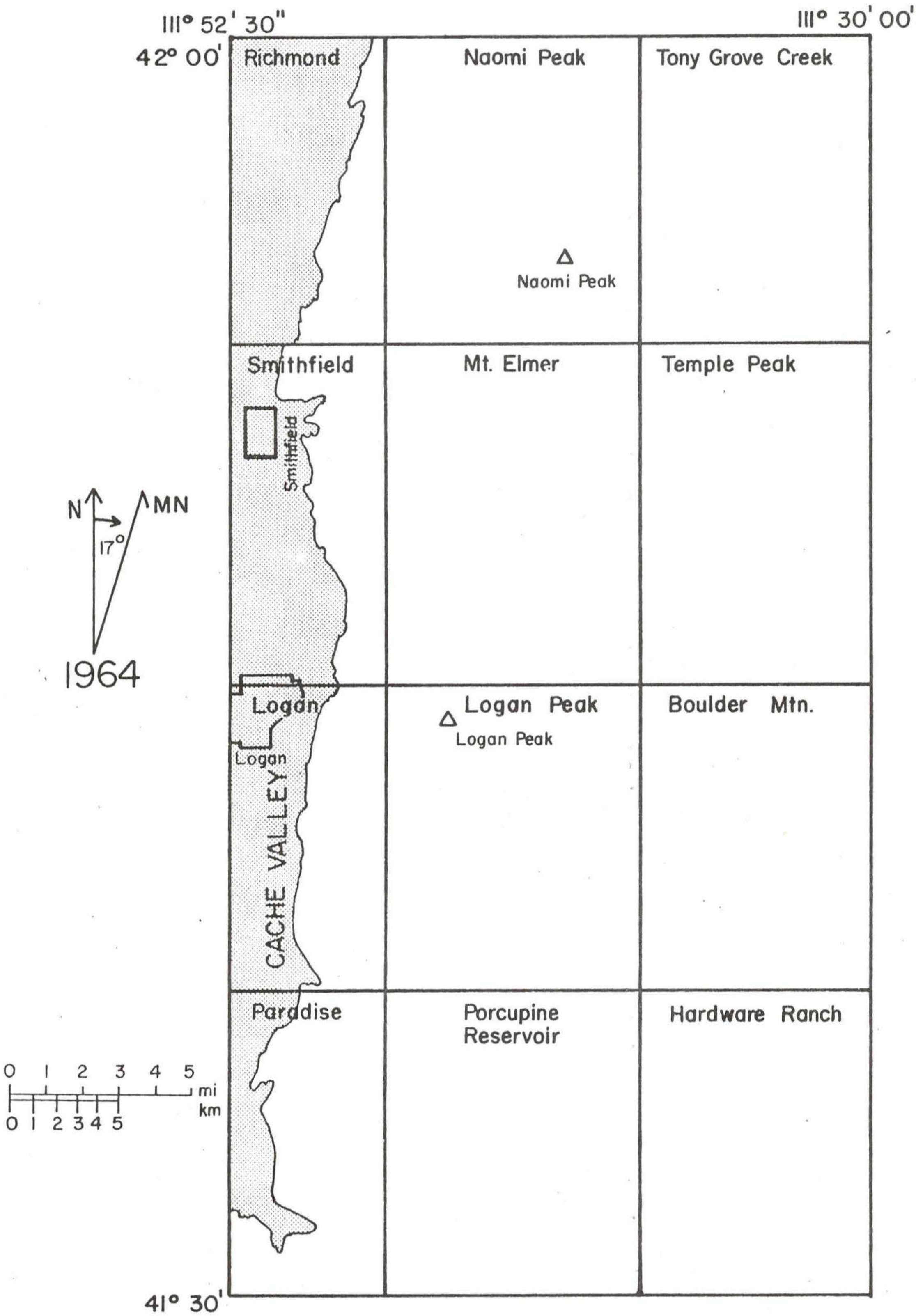

Figure 2. Map showing 7.5-minute topographic map coverage of the study area.

mountain areas in the southern part of the study area have few negotiable roads. State Highway 242 and unimproved roads in Providence, Millville, Hyrum, Paradise Dry, and East canyons provide vehicular access. Four-wheel drive vehicles can travel along a number of trails through this area. Except for the area between Blacksmith Fork and East canyons, the mountain land is administred by the U.S. Department of Agriculture, Forest Serivce. The rest of the land is controlled by the Utah Department of Fish and Wildlife or is privately owned and difficult to obtain permission for examination. Land north of Blacksmith Fork Canyon is controlled by the U.S. Department of Agriculture, Forest Serivce. Except for unimproved roads in High Creek, Smithfield, and Green canyons, vehicular travel is limited to U.S. Highway 89 along Logan Canyon. A number of small roads extend to selected points from U.S. Highway 89, but do not connect to other roads. This northern mountain area contains many trails and roads which can be negotiated by four-wheel drive vehicles. This part of the study area is criss-crossed with established hiking trails maintained by the Forest Service.

Field and Laboratory Work

A variety of field techniques were employed to investigate the Bear River Range. Aerial reconnaissance flights were conducted over the area in the Spring of 1974, Spring of 1975, and Fall of 1975. Over eight hours of air time were logged in either a Cessna 172 or 182. The most important features were photographed in 35 mm slide form for later scrutiny. The ground survey took place from May through early November 1974. Supplementary ground work to selected sites was conducted in the Spring and Fall of 1975. A number of areas, in the more rugged sectors of the Bear River Range, had to be reached by foot or horseback. The distances or access difficulties involved often required several days in travel time.

Laboratory work primarily involved the examination of collected material. Two thin sections were prepared from a rock sample collected at the mouth of Leatham Hollow. The sections are available from the Department of Geology, Utah State University for examination. Alluvial fans were sampled in Logan and Blacksmith Fork canyons to determine the relative amounts of gravel, sand, and fines (silt-plus-clay). Factors such as the presence of boulders, stratifications, and angularity were recorded for each sampling site. The samples were split, weighed, and sieved, and the sieved fractions weighed again. The values obtained were used to determine the relative percentages of gravel, sand, and fines in each sample. Measurements of alluvial fan parameters were derived from the 7.5-minute topographic quadrangle maps. The numerical values were gained through use of a Hewlett-Packard 9810A calculator system with an auxiliary digitizer. This system was capable of measuring areas and lengths based on map scales. Statistical analysis of the alluvial fan measurements (Appendix 1) were accomplished through use of the STATPAC programming library on the Burroughs 4700 computer at Utah State University

Previous Investigations

The geomorphology of the Bear River Range, Utah, has been studied previously only in selected areas or for certain processes or features. No previous work has attempted to deal with the geomorphic elements of the entire range in Utah.

Some geomorphic work has been included in studies dealing with other geologic problems. J. Stewart Williams (1948) dealt with some of the geomorphology in his study of the Paleozoic rocks in the Logan quadrangle. These and some additional topics such as landslides, were discussed in his publication on the geology of Cache County (Williams, 1958a). Several landslides were identified during an investigation of the geology of the Paradise 7.5-minute topographic quadrangle (Mullins and Izett, 1964).

Only three investigations deal with geomorphology exclusively. Two unpublished M.S. theses deal with geomorphic features in the Bear River Range. J. L. Young (1939) conducted a detailed survey of glaciated areas between Blacksmith Fork Canyon and the Utah-Idaho state line. He mapped erosional and depositional features resulting from glacial action. Additionally, he tried to establish a chronology of Pleistocene glacial events in this area. E. J. Williams (1964) studied the geomorphology of Logan Canyon. His area included the segment from the canyon mouth to the junction with Tony Grove Creek. His study encompasses a variety of geomorphic elements such as mass movements, glaciation, and solution features. J. Stewart Williams (1962) mapped Lake Bonneville deposits and features in detail. He outlined a chronology of events relating lake features to different levels of Lake Bonneville.

Geologic Setting

The rocks of the Bear River Range are sedimentary in origin. Rocks representing deposition during Precambrian and Paleozoic time are widely exposed (Williams, 1948, 1958a). Carbonate rocks predominate (Table 1), and account for about 55 percent of the thickness of the exposed stratigraphic column. About 50 percent of the section is sandstone and quartzite. Shale comprises a minor amount of the rocks in the Bear River Range. Refinement of the stratigraphy by recent studies has subdivided the basin units described by Williams (1948) without changing their character (Table 2). Past workers generally have assumed that these same formations are found beneath the valley floor. This assumption seems confirmed by recent geophysical studies (Peterson and Oriel, 1970; Stanley, 1962). Except for some outliers of Paleozoic rocks, only alluvium and outcrops of Tertiary and Quaternary formations are exposed

Table 1. Stratigraphic section in the Bear River Range.

Unit	Principal Composotion	Thickness (feet)
Quaternary System		
Post-lake deposits	Alluvial deposits	
Lake Bonneville Group	Lacustrine deposits	
Provo Formation		
Bonneville Formation		
Alpine Formation		
Tertiary System		
Salt Lake Formation	Sandstone and limestone	800[a]
Wasatch Formation	Conglomerate, mudstone, sandstone, and limestone	530[b]
Permian-Pennsylvanian Systems		
Oquirrh Formation	Sandstone and limestone	600[c]
Mississippian System		
Great Blue Formation	Limestone	725[c]
Little Flat Formation	Sandstone	800[c]
Lodgepole Formation	Limestone	750[c]
Mississippian-Devonian Systems		
Leathan Formation	Siltstone and dolostone	400[c]
Devonian System		
Beirdneau Formation	Dolostone and sandstone	1,087[d]
Hyrum Formation	Dolostone	932[d]
Water Canyon Formation	Dolostone and sandstone	495[e]
Ordivician-Silurian Systems		
Laketown Formation	Dolostone	1,422[f]
Ordovician System		
Fish Haven Formation	Dolostone	140[b]
Swan Peak Formation	Quartzite and shale	350[g]
Garden City Formation	Limestone and dolostone	1,405[h]
Cambrian System		
St. Charles Formation	Dolostone and quartzite	1,015[i]

Table 1. Stratigraphic section in the Bear River Range (Cont.).

Unit	Principal Composition	Thickness (feet)
Cambrian System (Cont.)		
Nounan Formation	Dolostone	1,125[j]
Bloomington Foramtion	Limestone and shale	1,495[j]
Blacksmith Formation	Dolostone	485[j]
Ute Formation	Limestone and shale	745[j]
Langston Formation	Dolostone, limestone shale, and siltstone	360[k]
Brigham Formation	Quartzite and shale	2,549[k]
Precambrian System		
Mutual Foramtion	Quartzite, purple and white	336[k]
Precambrian quartzite	Quartzite and shale	

[a]Smithfield (Adamson, Hardy, and Williams, 1955)
[b]Wellsville Mtn. (Williams, 1948)
[c]Paradise Quadrangle (Mullins and Izett, 1964)
[d]Blacksmith Fork Canyon (Williams, 1971)
[e]Water Canyon (Taylor, 1963)
[f]Tony Grove Lake (Budge, 1966)
[g]Green Canyon (VanDorston, 1969)
[h]Green Canyon (Ross, 1951)
[i]High Creek (Maxey, 1941)
[j]High Creek (Maxey, 1958)
[k]Birch Canyon (Galloway, 1970)

Table 2. William's 1948 stratigraphic names and their current equivalents.

Time Units	Stratigraphic Names Williams (1948)	 Current
Quaternary System		
	Alluvium	Lake Bonneville and post-lake deposits
Tertiary System		
	Salt Lake Formation	Salt Lake Formation
	Wasatch Formation	Wasatch Formation
Permian-Pennsylvanian		
	Wells Formation	Oquirrh Formation
Mississippian System		
	Brazer Foramtion	Great Blue and Little Flat Formations
	Madison Formation	Lodgepole and Leatham Formations
Devonian System		
	Jefferson Formation	Beirdneau, Hyrum, and Water Canyon Formations
Ordivician-Silurian System		
	Laketown Formation	Laketown Formation
Ordovician System		
	Swan Peak Foramtion	Fish Haven and Swan Peak Formations
	Garden City Formation	Garden City Formation
Cambrian System		
	St. Charles Formation	St. Charles Formation
	Nounan Formation	Nounan Formation
	Bloomington Formation	Bloomington Formation
	Blacksmith Formation	Blacksmith Formation
	Ute Formation	Ute Formation
	Langston Formation	Langston Formation
	Brigham Formation	Brigham Formation

Table 2. William's 1948 stratigraphic names and their current equivalents (Cont.).

Time Units	Stratigraphic Names: Williams (1948)	Stratigraphic Names: Current
Precambrian System		
	Bog Cottonwood Series	Mutual Formation and Precambrian quartzite

along the eastern valley margin (Williams, 1948, 1958a, 1962; Adamson, Hardy and Williams, 1955). The Quaternary Lake Bonneville Group and alluvium are exposed throughout the remainder of Cache Valley within the study area (Williams, 1962).

The study area includes parts of the Bear River Range and Cache Valley. Cache Valley is a north-trending, rather flat-floored valley which parallels the Bear River Range. The valley has dropped relative to the mountains to form a structural graben (Williams, 1948, 1958a; Mullins and Izett, 1964). The offset has occurred along faults along the valley margin adjacent to the western front of the Bear River Range. This fault zone continues to be active (Cook, 1971). Detailed studies have lead to the conclusion that displacement takes place on several west-dipping normal faults rather than a single fault plant (Williams, 1948, 1958a; Galloway, 1970; Mullins and Izett, 1964; Mendenhall, 1975).

The Bear River Range incorporates two major folds within the study area (Fig. 3). The Logan Peak syncline trends north-northwest near the western front of the range. The mountain front intersects the syncline just north of East Canyon (Williams, 1948). The Strawberry Valley anticline runs almost parallel to the Logan Peak syncline along the eastern part of the study area.

The tectonic evolution of the north-central Utah region can be related to the major geologic events of the western United States (Roberts, 1972). From the late Precambrian through Pennsylvanian-Permain time, this area was almost continuously a site of shallow-water, marine deposition. This conclusion is based on the origins and nearly continuous ages of rock formations presently exposed in the Bear River Range. Regional studies suggest that additional deposition through Triassic and Jurassic time may have taken place. Although earlier tectonic events affected this region, tectonic evolution of the present physiography

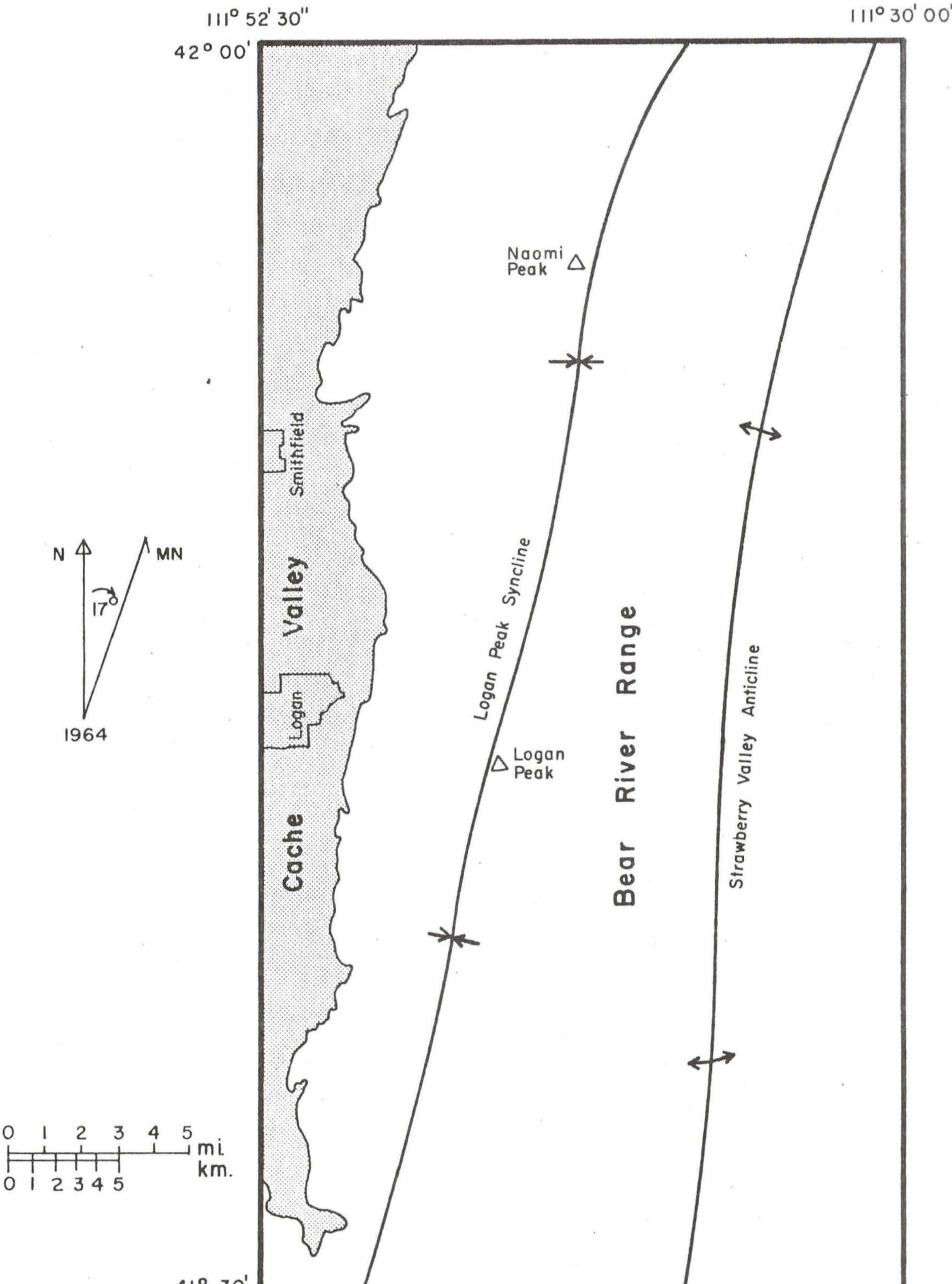

Figure 3. Locations of major folds in the Bear River Range.

took place during the Laramide orogeny. Uplift of the ancestral Bear River Range appears to have begun in the late Jurassic (Armstrong and Cressman, 1963). It is generally agreed that the folds now found in the range are Laramide in age (Williams, 1958a). In the early Tertiary, north-south normal faulting initiated the present overall Basin and Range topography including the Cache Valley graben. Restriction of the early Tertiary Wasatch Formation to accordant summits and valleys within the mountains and to downfaulted inliers along the valley margins, and the middle to late Tertiary Salt Lake Formation to valleys and valley margins supported this concept. The pediments cut on the Salt Lake Formation along the margins of Cache Valley indicate a quiesant period. Renewed movement on the normal faults between Cache Valley and the Bear River Range began in the late Tertiary and continues through the present. Erosion has continued to shape the mountainous terrain during this period (Fig. 4).

Lake Bonneville was an important pluvial lake during glacial parts of the Pleistocene Epoch. The lake underwent a number of fluctuations in level. Investigators have identified features and deposits associated with stable periods. The oldest stillstand recognized is the Alpine level, deposits of which are called the Alpine Formation. Studies in the Salt Lake Valley indicate that the Alpine level may correlate with the Bull Lake glaciation (Morrison, 1961). The Bonneville level and the younger Provo level appear to correlate with the Pinedale glaciation (Morrison, 1961). Cache Valley contained an extension of Lake Bonneville in north-central Utah. Extensive mapping has identified probable features of the Alpine level near 5,100 feet, those of the Bonneville level near 5,135 feet, and those of the Provo level near 4,800 feet (Williams, 1962). Some variation exists in the exact elevation of the Bonneville level at various points in Cache Valley (Crittenden, 1963). Age determinations suggest that the Alpine maximum was around 37,000 years ago. The Bonneville

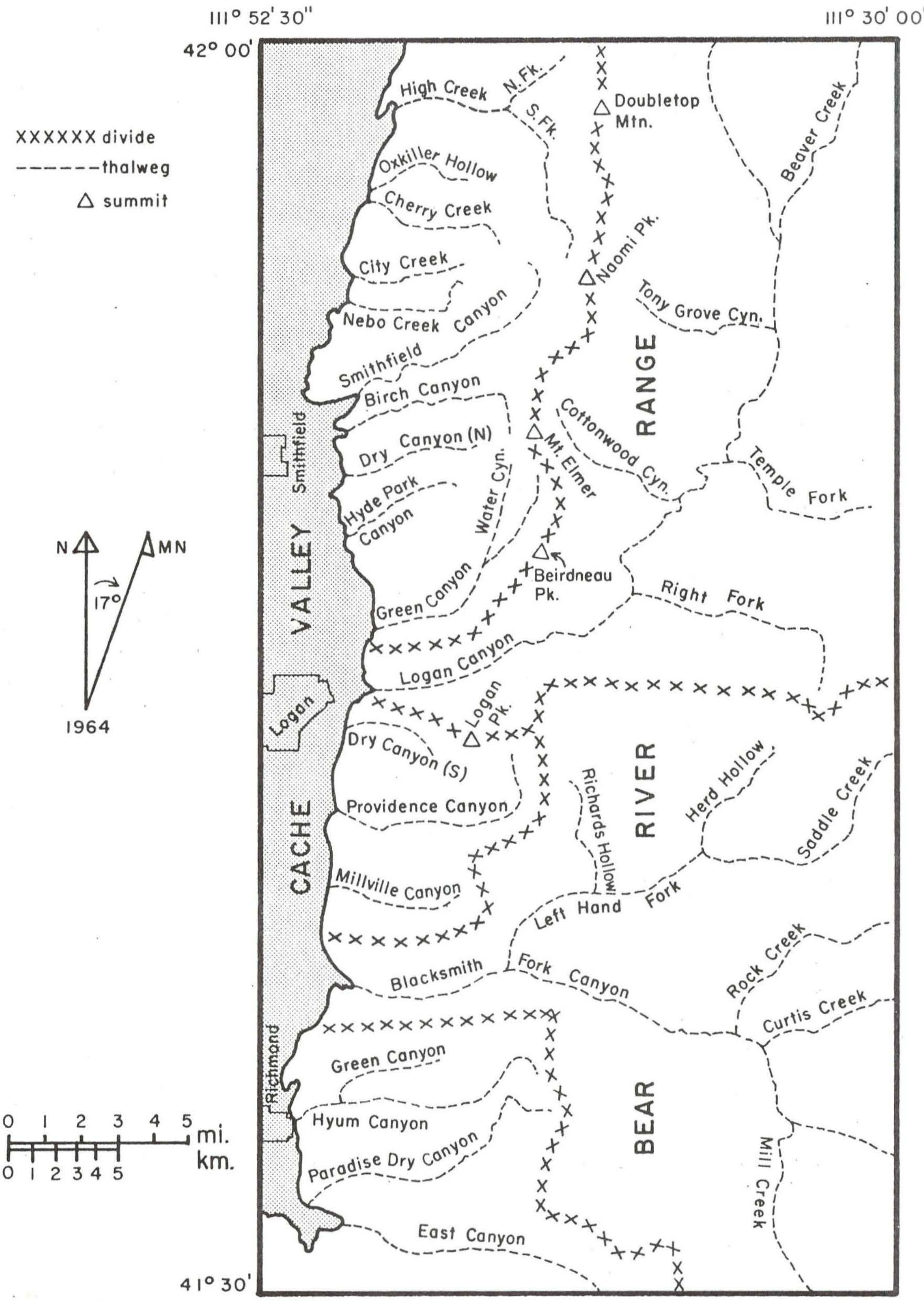

Figure 4. Locations of canyons within the Bear River Range.

maximum apparently was between 25,000 to 14,000 years ago (Broecker and Orr, 1958).

Red Rock Pass is located in Idaho at the north end of Cache Valley. Lake Bonneville overflowed at Red Rock Pass, and flooded a considerable extent of the Snake River Valley (Malde, 1968). This flood is related to Lake Thatcher in Gem Valley, Idaho. Prior to the flood at Red Rock Pass, Lake Thatcher had formed as a result of blocking and disruption of the Bear River by lava flows, probably along the present route of the Portneuf River to the Snake River. The impounded water formed Lake Thatcher in Gem Valley and eventually overflowed into Lake Bonneville through Oneida Narrows. The draining of Lake Thatcher took place about 27,000 years ago (Bright, 1963).

Some workers suggest that the overflow at Red Rock Pass happened about this same time as a result of the additional lake water and increased drainage via the Bear River (Malde, 1968). This concept seems substantiated by radiocarbon dates and analysis of soil development on related deposits. If the initial flood took place at this time, it pre-dates the Bonneville level. The relationship of Lake Bonneville and Lake Thatcher deposits in Gem Valley shows that the Bonneville level extended into the valley through Oneida Narrows (Bright, 1963). Sometime between 18,000 and 11,500 years ago, a flood over Red Rock Pass took place (Bright, 1963; Broecker and Orr, 1958). The outlet was subsequently graded to the Provo level. If the concept that the Bear River drainage alone provided the necessary water to create an overflow condition, then the flood between 18,000 and 11,500 years ago may have been the only Bonneville flood (Bright, 1963). It is possible that the overflow at the Bonneville level was the second flood to drain through Red Rock Pass (Malde, 1968). Based on the information accumulated, at least one and possibly two overflows took place.

PLEISTOCENE AND HOLOCENE FEATURES

Mass Movements

Mass movements are present in may parts of the Bear River Range. Features too small to map at a scale of 1:48,000 are not included. Also, the map does not include areas of slow mass movement such as soil creep or solifluction. All the mapped features are one acre or larger in size. Over 1,890 acres (2.95 square miles) of terraine have been disturbed by landslides. Individual slides or flows range in size from one acre to as much as 456 acres.

The classification of these features follows the system used in the compilation of Utah landslides (Schroder, 1971). The classification system is an adaptation of the classes defined by Varnes (1958). The classification system defines mass movements based on the speed of the movement and the type of material involved. The speed of movement is unknown for most of the features mapped. Depending on the material involved, the mapped features are defined as a rock-slip, debris-slip, or earth-slip. One of the mapped features, a sandflow, was observed to move rapidly. Another feature which is still active involves a number of units moving at a slow rate. On the basis of the type of material involved, this feature would ordinarily be classified as a debris-slide if no longer active. Instead, it is classified as a block-slide based on the observed rotational movement of units within the feature.

In describing each feature, the planar shape is given by the ratio of length (downslope) to width (parallel to contours). This number has been adjusted so that features which are equal in length and width have a value of 0. Features which are longer than wide have positive values greater than 0. Those which are wider than long have negative values less than 0.

Four parts of the Bear River Range contain mass movements which were identified and mapped. Landslides are present in Logan, Blacksmith Fork, and East canyons, and along the western front of the Bear River Range.

The northernmost canyon containing mass movements is Logan Canyon. Four features have been mapped in this area (Table 3).

The first feature is on the north side of Logan Canyon across from the Second Dam in Logan River, about 4.9 miles up Logan Canyon from the intersection of Main Street and 400 North in Logan. This location is represented on the Logan Peak 7.5-minute topographic map. This feature is classified as a rock-slip. The length-to-width ratio is +4.7. The material involved was derived by weathering from the Jefferson Formation. There is no evidence of current movement. The movement appears to have followed the dip slope. Undercutting of the canyon wall may have been responsible for the movement. This feature was originally described by E. J. Williams (1964).

The second feature is on the east side of Temple Fork Canyon, a tributary to Logan Canyon. It is just east of the junction of Temple Fork Creek and Spawn Creek, about 1.3 miles upstream from Logan Canyon. This feature is a debris-slip. This location is represented on the Temple Fork 7.5-minute topographic map. The length-to-width ratio is +0.2. The material involved was derived by weathering from the Wasatch Formation. There is no indication of current movement. Movement may have resulted from undercutting of the slope by lateral erosion of Temple Creek.

The third feature is on the east side of Logan Canyon, 0.7 mile south of the junction of West Hodges Creek and the Logan River. This location is represented on the Temple Fork 7.5-minute topographic map. This feature is a debris-slip. The length-to-width ratio is +1.3. The material involved was derived by weathering from the Wasatch Formation. There is no evidence of current movement. Movement may have been initiated by undercutting of the bank

Table 3. Mass movements mapped in the Bear River Range.

Feature	Scarp Elev. (ft)	Toe Elev. (ft)	Relief (ft)	Aspect	Slope (°)	Slope (%)	Area Acres	Area Hect.
1	5,280	5,040	240	SE	15	27	7	3
2	6,240	6,000	240	SW	12	21	26	11
3	6,600	6,080	520	W	20	36	19	8
4	6,480	6,240	240	NW	13	23	12	5
5	6,720	6,240	480	W	20	36	45	18
6	6,480	6,280	200	W	14	25	6	2
7	5,640	5,280	360	NW	28	53	6	2
8	6,600	5,800	800	NW	11	19	122	49
9	6,640	6,200	440	SW	12	21	45	18
10	7,000	6,720	280	N	16	27	6	2
11	6,800	6,680	120	N	9	16	6	2
12	7,000	6,680	320	SW	18	32	13	5
13	6,720	6,600	120	SW	17	31	6	2
14	6,680	6,400	280	W	19	34	13	5
15	6,800	6,480	320	NW	13	23	186	75
16	5,880	5,360	520	N	30	58	6	2
17	5,760	5,560	200	W	12	21	6	2
18	5,880	5,600	280	W	19	34	13	5
19	6,600	6,000	600	NW	11	19	122	49
20	6,400	6,000	400	W	18	32	19	8
21	6,760	6,040	720	W	15	27	96	39
22	6,080	5,360	720	SW	20	36	45	18
23	6,160	5,920	240	SE	16	27	13	5
24	5,520	5,400	120	SE	6	11	19	8

Table 3. Mass movements mapped in the Bear River Range (Cont.)

Feature	Scarp Elev. (ft)	Toe Elev. (ft)	Relief (ft)	Aspect	Slope		Area	
					(°)	(%)	Acres	Hect.
25	5,440	5,240	200	W	20	36	6	2
26	5,400	5,200	200	N	19	34	9	4
27	5,680	5,000	680	W	18	33	95	38
28	5,600	5,040	560	NW	24	44	41	16
29	5,320	5,160	160	NW	24	44	6	2
30	5,600	5,160	440	W	12	21	29	12
31	6,040	5,560	480	SW	13	23	456	182
32	5,760	5,240	520	W	16	28	62	25
33	6,200	5,480	720	W	12	22	78	31
34	7,640	6,040	1,600	W	19	35	45	18
35	5,040	4,920	120	S	6	11	17	7
36	5,800	5,120	680	SW	27	51	19	8
37	4,880	4,800	80	W	9	16	9	4
38	4,800	4,720	80	E	22	40	1	--
39	5,400	5,040	360	NW	9	16	95	38
40	5,440	5,120	280	NW	10	17	65	26

by the Logan River, by glacial erosion, or by both.

The fourth feature is on the east side of Logan Canyon just south of the junction between Little Bear Creek and the Logan River. The site is adjacent to the Utah State University Forestry Field Station. This location is represented on the Tony Grove Creek 7.5-minute topographic map. The feature is a debris-clip. The length-to-width ratio is +1.0. The material involved was derived by weathering from the Wasatch Formation. There is no indication of current activity. Undercutting of the slope through erosion by the Logan River, Little Bear Creek, or glacial ice created the unstable condition responsible for this movement.

The fifth feature is on the east side of Logan Canyon about 0.3 mile north of the Utah State University Forestry Field Station. The northern edge of the feature is directly east of the intersection of U. S. Highway 89 and the U. S. Forest Service road to Tony Grove Lake. This location is represented on the Tony Grove Creek 7.5-minute topographic map. This feature is a debris-slip. The length-to-width ratio is -0.3. The material involved was derived by weathering from the Wasatch Formation. There is no evidence of current movement. Movement may have been caused by undercutting of the slope by the Logan River or by glacial ice.

The sixth feature is on the east side of Logan Canyon about 0.4 mile north of the Utah State University Forestry Field Station. It occupies the same general site as feature five near the northern (upstream) end. The feature is debris-slip. The length-to-width ratio is +0.4. The material involved was derived by weathering from the Wasatch Formation. There is no indication of current movement. The cause of this movement is probably the same as for feature five.

The large number of mass movements mapped in Blacksmith Fork Canyon include many located along the Left Hand Fork tributary. The upper reaches of Left Hand Fork along Saddle Creek are the most prone to slippage. Fifteen features have been mapped in drainage of Blacksmith Fork Canyon (Table 3).

The seventh feature is in Blacksmith Fork Canyon east of the Hyrum City power plant. It is on the south side of the canyon 0.1 mile east of the Hyrum City Park. The location is represented on the Logan Peak 7.5-minute topographic map. This feature is a rock-slip. The length-to-width ratio is +4.7. The material involved is derived from the St. Charles Formation. There is no evidence of current movement.

The eighth feature is in the canyon of the Left Hand Fork tributary to Blacksmith Fork Canyon. It is on the south side of the canyon directly across from Gray Cliffs Spring. This location is represented on the Boulder Mountain 7.5-minute topographic map. This feature is a debris-slip. The length-to-width ratio is +1.1. The material involved probably was derived by weathering from the Bloomington Formation. There is no indication of current movement. Movement may be related to unstable slopes resulting from faulting. A normal fault is mapped (Williams, 1948) adjacent to the southwestern margin of the feature. The debris-slip is on the downdropped side of the fault.

The ninth feature is on the north side of Rock Creek valley, just east of the Hardware Ranch-Danish Dugway road. It is in Sec. 32, T. 11 N., R. 4 E. This location is represented on the Boulder Mountain 7.5-minute topographic map. This feature is a debris-slip. It has a length-to-width ratio of +0.7. The material involved was derived by weathering from the Brigham Formation. There is no evidence of current movement. The debris-slip is bordered by two normal faults (Williams, 1948). The feature is situated on a downdropped block. Unstable slopes created by past movement on the faults may have resulted in mass movement.

The tenth feature is along the Hardware Ranch-Danish Dugway road at a point where it crosses an intermittent stream. This site is 0.2 mile east of the connecting road to Saddle Creek and Elk Valley. The feature is in Sec. 20, T. 11 N., R. 4 E. The location is represented on the Boulder Mountain 7.5-minute topographic map. The feature is a debris-slip. The length-to-width ratio is +1.8. The material involved was probably by weathering from the Brigham Formation. There is no indication of current movement.

The eleventh feature is along the road connecting the Hardware Ranch-Danish Dugway road to the Saddle Creek-Elk Valley road. The site is 0.2 mile north along the road in Sec. 20, T. 11 N., R. 4 E. The location is represented on the Boulder Mountain 7.5-minute topographic map. The feature is a debris-flow. Rapid movement is shown by the torn bark of aspen trunks in the stable areas along the margin of the flow. The length-to-width ratio is +0.5. The material involved was probably derived by weathering from the Wasatch Formation. The most recent movement occurred in the spring of 1974. A number of aspen trees were swept along with the flow material. Trees adjacent to the flow were battered and scraped by trees carried by the movement. Debris blocked the road necessitating excavation and repair by U. S. Forest Service road crews.

The twelfth feature is along the raod connecting the Hardware Ranch-Danish Dugway road to the Saddle Creek-Elk Valley road. The site is 0.4 mile north along the road in Sec. 20, T. 11 N., R. 4 E. This location is represented on the Boulder Mountain 7.5-minute topographic map. This feature is a debris-slip. The length-to-width ratio is +0.2. The material involved was probably derived by weathering from the Brigham Formation. There is not indication of current movement.

The thirteenth feature is along the road connecting the Hardware Ranch-Danish Dugway road to the Saddle Creek-Elk Valley road. The site extends 0.6

mile along the road in Secs. 17 and 20, T. 11 N., R. 4 E. This location is represented on the Boulder Mountain 7.5-minute topographic map. This feature is a debris-slip. The length-to-width ratio is +0.7. The material involved was probably derived by weathering from the Brigham Formation. There is no indication of current movement.

The fifteenth feature is the Saddle Creek landslip zone. This zone is on the southeast side of Saddle Creek Valley. It extends for a distance of approximately 1.5 miles northward from near the junction between Dip Hollow road and the Saddle Creek-Elk Valley road. The site is in Secs. 8 and 9, T. 11 N., R. 4 E. This location is represented on the Boulder Mountain 7.5-minute topographic map. The mappable landslips in this zone are earth-slips. Approximately 40 percent of the terrain included within the zone is undisturbed. The length-to-width ratio of the zone is -0.8. The material involved was derived by weathering from the Wasatch Formation. Recent movement along the zone is evidenced by sag ponds, recent ground cracks near the scarps, and trees bent in response to slower ground movement. A fault parallels the upper boundary of the landslip zone (Cluff and Others, 1975). The landslip zone is on the downdropped side. Displacement on this fault has contributed to the instability of this side of Saddle Creek Valley. This contributing factor and the nature of the material involved has led to the creation of the Saddle Creek landslip zone.

The sixteenth feature is along State Highway 101 about 3.0 miles west of Hardware Ranch. The site is on the south side of Blacksmith Fork Canyon in Sec. 17, T. 10 N., R. 3 E. This location is represented on the Hardware Ranch 7.5-minute topographic map. This feature is a rock-slip. The length-to-width ratio is +1.5. The material involved was derived by weathering from the Brigham Formation. There is no evidence of current movement.

The seventeenth feature is about 0.2 mile south of Hardware Ranch along

the road leading south to Anderson Ranch. This site is on the east side of Blacksmith Fork Canyon in Sec. 14, T. 10 N., R. 3 E. This location is represented on the Hardware Ranch 7.5-minute topographic map. The feature is a debris-slip. The length-to-width ratio is 0. The material involved was derived by weather from the Wasatch Formation. There is no indication of current movement.

The eighteenth feature is about 0.6 mile south of Hardware Ranch along the road leading south to Anderson Ranch. This site is on the east side of Blacksmith Fork Canyon in Sec. 14, T. 10 N., R. 3 E. This location is represented on the Hardware Ranch 7.5-minute topographic map. The feature is a debris-slip. The length-to-width ratio is -0.4. The material involved was derived by weathering from the Wasatch Formation. The toe of the slide is at road level. This fact combined with the relatively fresh appearance suggests that the slide may have been triggered by original road construction along the slope. There is no evidence of current movement.

The nineteenth feature is on the east side of Sheep Creek Valley just south of the junction of sheep Creek Valley and Petes Hollow. The site is in Sec. 36, T. 10 N., R. 3 E. This location is represented on the Hardware Ranch 7.5-minute topographic map. The feature is a debris-slip. The length-to-width ratio is 0.7. The material involved was derived by weathering from the Wasatch Formation. There is no indication of current movement.

The twentieth feature is on the east side of Sheep Creek Valley about 1.0 mile south of the junction of Sheep Creek Valley and Petes Hollow. This site is adjacent to the south margin of feature nineteen. This location is represented on the Hardware Ranch 7.5-minute topographic map. The feature is a debris-slip. The length-to-width ratio is +0.2. The material involved was derived by weathering from the Wasatch Formation. There is no evidence of current movement.

The southernmost canyon containing identified and mapped mass movements is East Canyon. Two mass movements were mapped by Mullins and Izett (1964). These features are described in Table 3.

The twenty-second feature is about 2.1 miles east along the La Plata road near the mouth of East Canyon. This site is in Secs. 7 and 18, T. 9 N., R. 2 E. This location is represented on the Paradise 7.5-minute topographic map. The feature is a debris-slip. The length-to-width ratio is +1.4. The material was derived by weathering from the Brazer Formation. There is no evidence of current movement. The debris-slip has undergone a significant amount of erosional modification resulting in a subdued morphology. This debris-slip was mapped by Mullins and Izett (1964).

The twenty-third feature is about 2.6 miles east along La Plata road near the mouth of East Canyon. This site is in Secs. 7 and 18, T. 9 N., R. 2 E. This location is represented on the Paradise 7.5-minute topographic map. The feature is a debris-slip. The length-to-width ratio is -0.3. The material involved was derived by weathering from the Brazer Formation. There is no indication of current activity. In terms of relative age, this feature resembles feature twenty-two. This debris-slip was mapped by Mullins and Izett (1964).

The twenty-fourth feature is at the edge of Porcupine Reservoir near the right abutment of the dam. This location is represented on the Paradise 7.5-minute topographic map. This feature is the only one classified as a blockslide. Movement is slow. A number of units exhibit rotation. The length-to-width ratio is -0.2. The material was derived by weathering from the Wasatch Formation. The blockslide is currently active. Fresh cracks are visible near the scarp and at several points on the slide mass. The upper mass of the slide consists of rotated blocks. There is some flowage within the mass near the toe. It appears that the area along the bottom of the slope may have been excavated during the

construction of Porcupine Reservoir dam. This work may have undercut the slope in this area. A high water table, which occurs in the spring when the reservoir is filled, probably contributed importantly to movement.

Sixteen mass movements are found along the western front of the Bear River Range. These features are described from north to south (Table 3).

The twenty-fifth feature is north of the mouth of High Creek Canyon. The site is in Secs. 5 and 6, T. 14 E., R. 2 E. This location is represented on the Richmond 7.5-minute topographic map. The feature is a debris-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is -0.1. The material involved was derived by weathering from the Salt Lake Formation. The Salt Lake Formation in this area is mapped as a fanglomerate (Williams, 1948). There is no indication of current movements.

The twenty-sixth feature is at the north side of the mouth of High Creek Canyon. The site is in Sec. 6, T. 14 N., R. 2 E. and Sec. 31, T. 15 N., R. 2 E. This location is represented on the Richmond 7.5-minute topographic map. This feature is a debris-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is -0.4. The material involved is derived from the Salt Lake Formation. The Salt Lake Formation in this area is mapped as a fanglomerate (Williams, 1948). There is no evidence of current movement.

The twenty-seventh feature is north of the moutn of High Creek Canyon. The site is just south of the second feature in Sec. 6, T. 14 N., R. 2 E. This location is represented on the Richmond 7.5-minute topographic map. The feature is debris-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is -0.4. The material was derived by weathering from the Salt Lake Formation. The Salt Lake

Formation in this area is mapped as a fanglomerate (Williams, 1948). There is no evidence of current movement.

The twenty-eighth feature is north of the mouth of High Creek Canyon. The site is just south of the third feature in Sec. 6, T. 14 N., R. 2 E. This location is represented on the Richmond 7.5-minute topographic map. The feature is a debris-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is -0.3. The material was derived by weathering from the Salt Lake Formation. The Salt Lake Foramtion in this area is mapped as a fanglomerate (Williams, 1948). There is no indication of current movement.

The twenty-ninth feature is just north of the mouth of Oxkiller Hollow. The site is in Secs. 18 and 19, T. 14 N., R. 2E. and Secs 13 and 24, T. 14 N., R. 2 E. This location is represented on the Richmond 7.5-minute topographic map. The feature is a debris-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is -0.7.. The material was derived by weathering from the Salt Lake Formation. The Salt Lake Formation in this area is mapped as a fanglomerate (Williams, 1948). There is no evidence of current movement.

The thirtieth feature is just north of the mouth of Cherry Creek Canyon. The site is in Sec. 19, T. 14 N., R. 2 E. and Sec. 24, T. 14 N., R. 2 E. This location is represented on the Richmond 7.5-minute topographic map. The feature is a rock-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is -0.7. The rock material involved in this movement was derived by weathering from the conglomerate member of the Salt Lake Formation (Mendenhall, 1975). There is no indication of current movement.

The thirty-first feature is on the north slope of Cherry Creek Canyon. The site is in Secs. 19 and 30, T. 14 N., R. 2 E. The location is represented

on the Richmond 7.5-minute topographic map. The feature is a rock-slip. This movement was mapped by Mendenhall (1975). The length-to-width ratio is +0.9. The rock material involved in the movement was derived by weathering from the conglomerate member of the Salt Lake Formation (Mendenhall, 1975). There is no evidence of current movement.

The thirty-second feature is directly east of Richmond in Sec. 24, T. 14, N., R. 1 E. The location is represented on the Richmond 7.5-minute topographic map. The feature is a debris-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is 0. The material involved in the movement was derived by weathering from the Salt Lake Formation. The Salt Lake Formation in this area is mapped as a fanglomerate (Williams, 1948). There is no evidence of current movement.

The thirty-third feature is in Secs. 6 and 7, T. 13 N., R. 2 E. and Secs. 31 and 32. T. 14 N., R. 2 E. This location is represented on the Naomi Peak and Richmond 7.5-minute topographic maps. The feature is a rockslip. The length-to-width ratio is -0.4. The material involved was derived from the Garden City and St. Charles Formations (Mendenhall, 1975). Previous investigation has shown that the toe of the feature is covered by deposition of Salt Lake Formation (Mendenhall, 1975). Movement took place prior to deposition in the tertiary. There is no evidence of movement occurring since that time.

The thirty-fourth feature is in Secs. 25 and 36, T. 14 N., R. 1 E. and Secs. 30 and 31, T. 14 N., R. 2 E. This location is represented on the Richmond 7.5-minute topographic map. The feature is a debris-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is +2.0. The material involved in the movement was derived by weathering from the Salt Lake Formation. The Salt Lake Formation in this area is mapped as a fanglomerate (Williams, 1948). There is no indication of current movement.

The thirty-fifth feature is on the north side of Smithfield Canyon near the canyon mouth. The site is in Sec. 23, T. 13 N., R. 1 E. This location is represented on the Smithfield 7.5-minute topographic map. The feature is a debris-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is +0.3. The material involved in the movement was derived from the Lake Bonneville level (Williams, 1962). There is no evidence of current movement.

The thirty-sixth feature is just south of the mouth of Birch Canyon. The site is in Sec. 25, T. 13 N., R. 1 E. This location is represented on the Smithfield 7.5-minute topographic map. The feature is a debris-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is +1.4. The material involved in the movement was derived by weathering from the Salt Lake Formation. The Salt Lake Formation in this area is mapped as a fanglomerate facies (Williams, 1948). There is no indication of current movement.

The thirty-seventh feature is just east of Millville. The site is in Sec. 23, T. 11 N., R. 1 E. This location is represented on the Logan 7.5-minute topographic map. The feature is a debris-slip. The boundaries of this movement were mapped during a previous investigation (Cluff and others, 1975). The length-to-width ratio is -0.4. The material involved in the movement was derived from the Lake Bonneville group. This area is mapped as silt and fine sand deposited during the Bonneville level (Williams, 1962). There is no evidence of current movement.

The thirty-eighth feature is in the valley of the Blacksmith Fork River just downstream from the mouth of Blacksmith Fork Canyon. The site is about 0.4 mile northwest along the county road between State Highway 242 and Nibley, Utah. This location is represented on the Blacksmith Fork 7.5-minute topographic

map. The feature is a sandflow. The length-to width ratio is +0.5. The material involved in the movement was derived from the Lake Bonneville group. The sediments are silt, sand, and gravel deposited in a Lake Bonneville delta at the Provo level (Williams, 1962). The sandflow occurred in May of 1974. Efforts to stabilize the disturbed area resulted in another movement in August of 1974. The probable causes of this mass movement is an oversteepened slope resulting from erosion by the Blacksmith Fork River. The oversteepened slope intersects horizontal beds of silt, sand, and grave. Ground water flows along the gravel layer about 50 feet from the top of the escarpment. Oversaturation of the sand layers adjacent to the gravel layer resulted in failure of the slope. This oversaturation was due to spring runoff in the first movement and probably, due to irrigation water in the second movement. There has been no additional movement since pipe was installed to de-water the gravel layer at the escarpment.

The thirty-ninth feature is just north of the McKenzie Flat near the mouth of East Canyon. The site is Secs. 11 and 14. T. 9 N., R. 1 E. The location is represented on the Paradise 7.5-minute topographic map. The feature is a debris-slip. The length-to-width ratio is -0.1. The material involved was derived from the Lake Bonneville group. This area is mapped as Provo level sediments (Williams, 1962). There is no indication of current movement.

The fortieth feature is on the east side of South Fork Canyon. The site is in Secs. 14 and 23, T. 9 N., R. 1 E. The location is represented on the Paradise 7.5-minute topographic map. The feature is a debris-slip. The length-to-width ratio is +0.1. The material involved in the movement was derived from the Lake Bonneville group. This area is mapped as Provo level sediments (Williams, 1962). There is no indication of current movement.

The following summarizes the factors controlling and contributing to landslides in the Bear River Range in Utah. The major factors include lithologies, aspect, elevation, and slope.

Stratigraphic units involved in landslides include formations of Quaternary, Tertiary, Mississippian, Devonian, Ordovician, and Cambrian age (Fig. 5).

The Quaternary stratigraphic units involved in landslides are formations of the Lake Bonneville Group. The Lake Bonneville Group is composed of unconsolidated sand, gravel, and silt. These beds are usually horizontal or dip gently toward the center of Cache Valley. The Lake Bonneville Group is found along the margins of Cache Valley along the mountain front. Five landslides involve this stratigraphic unit. This represents twelve percent of all mapped landslides in the study area. A total of 187 acres or 9.9 percent of the disturbed area mapped involves the Lake Bonneville Group. The mean landslide involving this stratigraphic unit is 37.4 acres.

The Tertiary stratigraphic units involved in landslides are the Salt Lake Formation and Wasatch Formation. The Salt Lake Formation of late and middle Tertiary age is usually restricted to the margins of Cache Valley and some valleys within the Bear River Range. The Salt Lake Formation is composed of tuffaceous and conglomeratic members. Ten landslides involve this stratigraphic unit. This represents twenty-five percent of all mapped landslides in the study area. A total of 801 acres or 42.3 percent of the disturbed area mapped involves the Salt Lake Formation. The mean landslide involving this stratigraphic unit is 80.1 acres. The Wasatch Formation of early Tertiary age is found as downfaulted inlier along the margins of Cache Valley, and in mountain valleys and on accordant summits. The Wasatch Formation is composed of mudstone and conglomerate members. Thirteen landslides involve this stratigraphic unit. This represents thirty-two percent of all mapped landslides in the study area. A total of 575 acres or 30.4 percent of the distrubed area mapped involves the

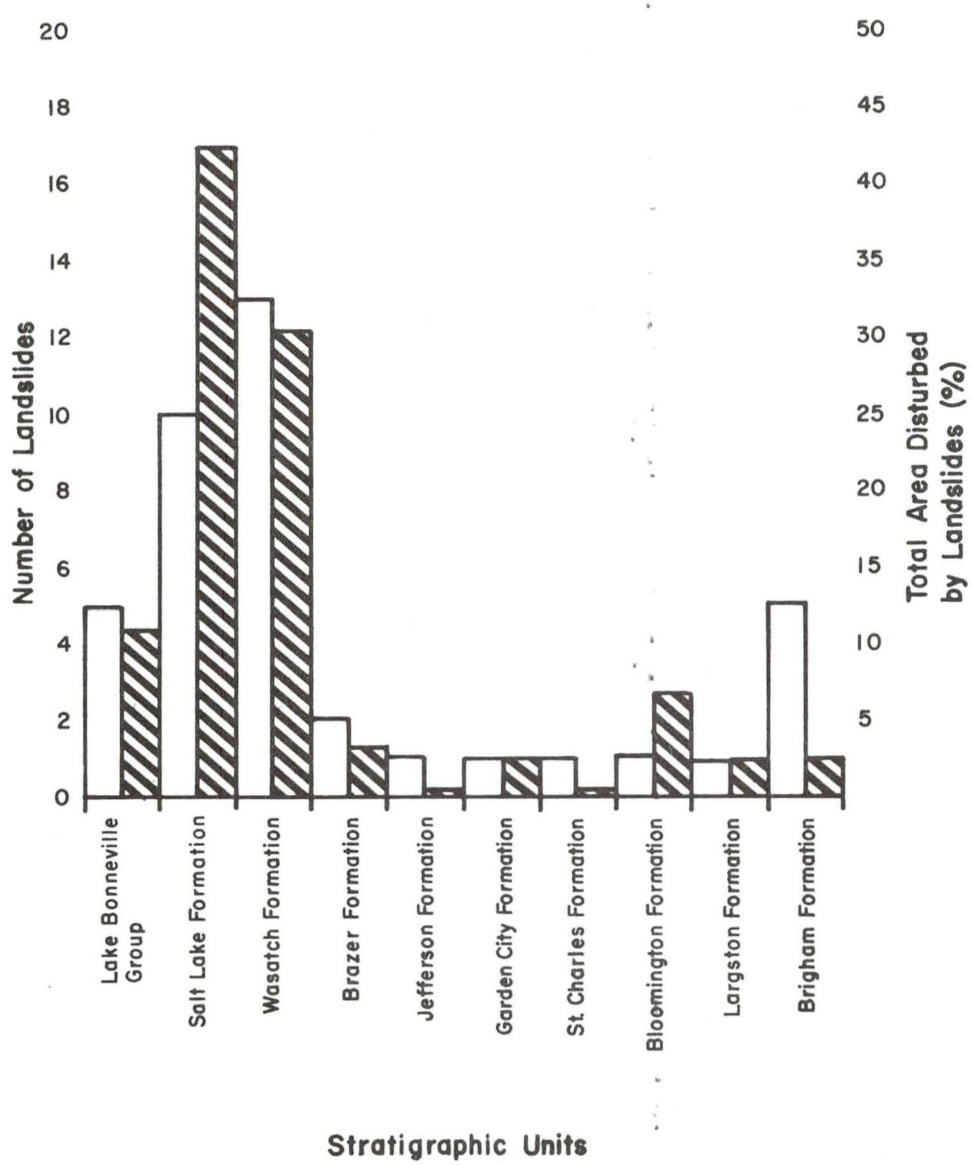

Figure 5. Graphic representation of landslides correlated with stratigraphic units.

Wasatch Formation. The mean landslide involving this stratigraphic unit is 44.2 acres.

The Mississippian stratigraphic unit involved in landslides is the Brazer Formation. The Brazer Formation consists of beds of limestone and sandstone. Two landslides involve this stratigraphic unit. This represents four percent of all mapped landslides in the study area. A total of 58 acres or 3.1 percent of the disturbed area mapped involves the Brazer Formation. The mean landslides involving this stratigraphic unit is 29.0 acres.

The Devonian stratigraphic unit involved in landslides is the Jefferson Formation. The Jefferson Formation consists of dolostones and sandstones. One landslide involves this stratigraphic unit. This represents three percent of all mapped landslides in the study area. A total of 7 acres or 0.4 percent of the distrubed area mapped involved the Jefferson Formation. The mean landslide involving this stratigrphic unit is 7.0 acres.

The Ordovician stratigraphic unit involved in landslides is the Garden City Formation. The Garden City Formation consists of limestone and dolostone. One landslide involves this stratigraphic unit. This represents three percent of all mapped landslides in the study area. A total of 45 acres or 2.4 percent of the disturbed area mapped involves the Garden City Formation. The mean landslide involving this stratigraphic unit is 45.0 acres.

The Cambrian stratigraphic units involved in landslides are the St. Charles, Bloomington, Langston, and Brigham Formations. The St. Charles Formation is composed of dolostone and quartzite. One landslide involves this stratigraphic unit. This represents three percent of all mapped landslides in the study area. A total of 6 acres or 0.3 percent of the distrubed area mapped involves the St. Charles Formation. The mean landslide involving this stratigraphic unit is 6.0 acres. The Bloomington Formation is composed of limestone and shale.

One landslide involves this stratigraphic unit. This represents three percent of all mapped landslides in the study area. A total of 122 acres or 6.5 percent of the distrubed area mapped involves the Bloomington Formation. The mean landslide involving this stratigraphic unit is 122.0 acres. The Langston Formation is composed of dolostone, limestone, shale, and siltstone. One landslide involves this stratigraphic unit. This represents three percent of all mapped landslides in this study area. A total of 45 acres or 2.4 percent of the distrubed area mapped involves the Langston Formation. The mean landslide involving this stratigraphic unit is 45.0 acres. The Brigham Formation is composed of quartzite and shale. Five landslides involve this stratigraphic unit. This represents twelve percent of all mapped landslides in the study area. A total of 44 acres or 2.3 percent of the disturbed area mapped involves the Brigham Formation. The mean landslide involving this stratigraphic unit is 8.8 acres.

Based on the landslides mapped in the study area, Tertiary stratigraphic units are the most prone to landslides. It is often the conglomerate member with a high percentage of clay in the matrix that is incorporated into the landslide. The conglomerate member moves due to loss of support. Failure of the tuffaceous member of the Salt Lake Formation causes large scale slumping by the conglomerate member. Failure of the mudstone member of the Wasatch Formation results in sliding by the conglomerate member. In both cases, landslides involve movement of coarse-grained units as a result of failure in the underlying fin-grained unit. In addition to being the most frequently disturbed stratigraphic units, the Salt Lake and Wasatch formations account for 72.7 percent of the total area disturbed by landslides and have some of the largest average landslides.

Aspect is another variable that influences the location of landslides in the Bear River Range (Fig. 6). Slopes with a west aspect or with an aspect with a west-component are most prone to landsliding. Ninety-five and 6/10 percent of the area disturbed by landslides is located on slopes with these aspects. In addition, landslides on slopes with a west or west-component aspect are more numerous and of larger size than on other slope aspects. This potential for landslides on west or west-component aspects probably reflects the effect of higher diurnal temperature ranges. This tends to increase water in the soil by melting snow and ice which is the predominate precipitation in the area. These slope aspects would receive less snow accumulation and be blow free of snow more frequently than slopes with other aspects.

The elevation of landslides can be a controlling factor (Fig. 7). The study area can be divided into about six elevation zones of five thousand feet per interval. Of these six zones, only four contain landslides. Ten acres or one percent of the area disturbed by landslides is found within this zone. The next elevation zone is between 5,000 to 5,999 feet. Five hundred and one acres or 27 percent of the area disturbed by landslides is located within this zone. In the zone between 6,000 to 6,999 feet, 1,315 acres or 69 percent of the area disturbed by landslides is found in this zone. The zone between 7,000 to 7,999 feet contains 64 acres or three percent of the area disturbed by landslides. The preponderance of landslides in the elevation zone from 6,000 to 6,999 feet reflects the amount of the study area with gentle or steep slopes. The lower elevations contain a majority of the gentle slopes. The 6,000 to 6,999 feet elevation zone includes the steeper slopes but excludes many of the steepest slopes where other factors reduce landslide potential.

Slope is frequently an important controlling factor in the location of landslides. The average slope for landslides in the Bear River Range is 27

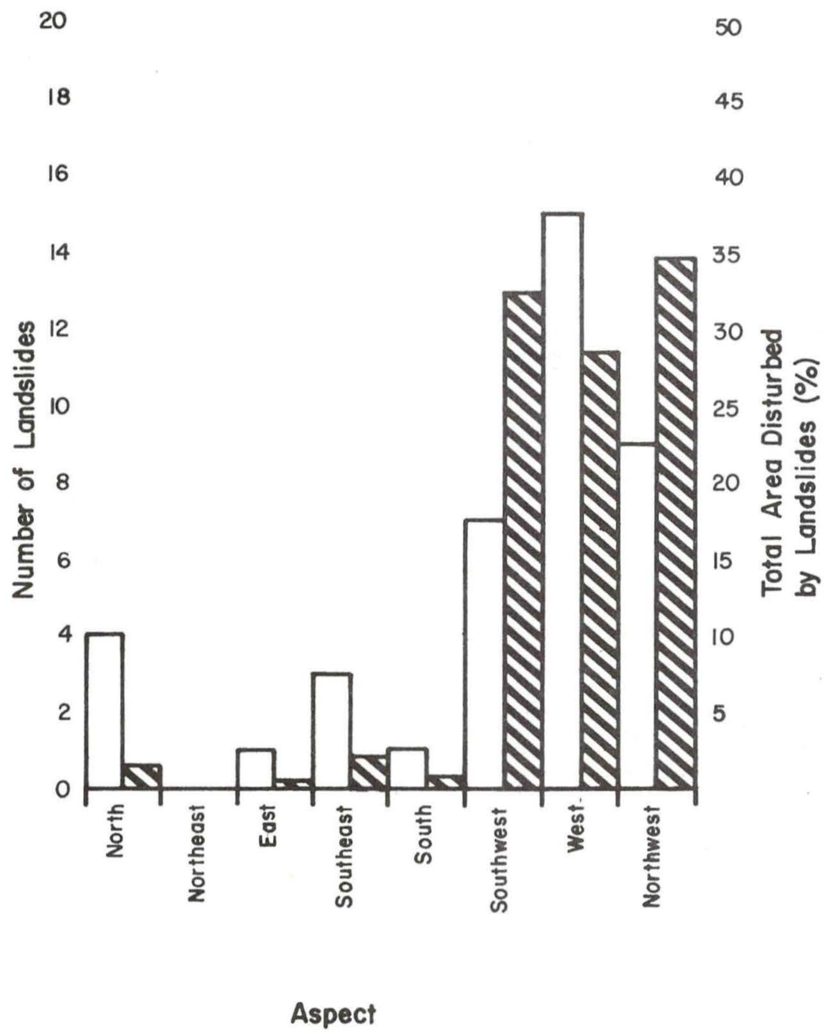

Figure 6. Graphic representation of landslides correlated with aspect.

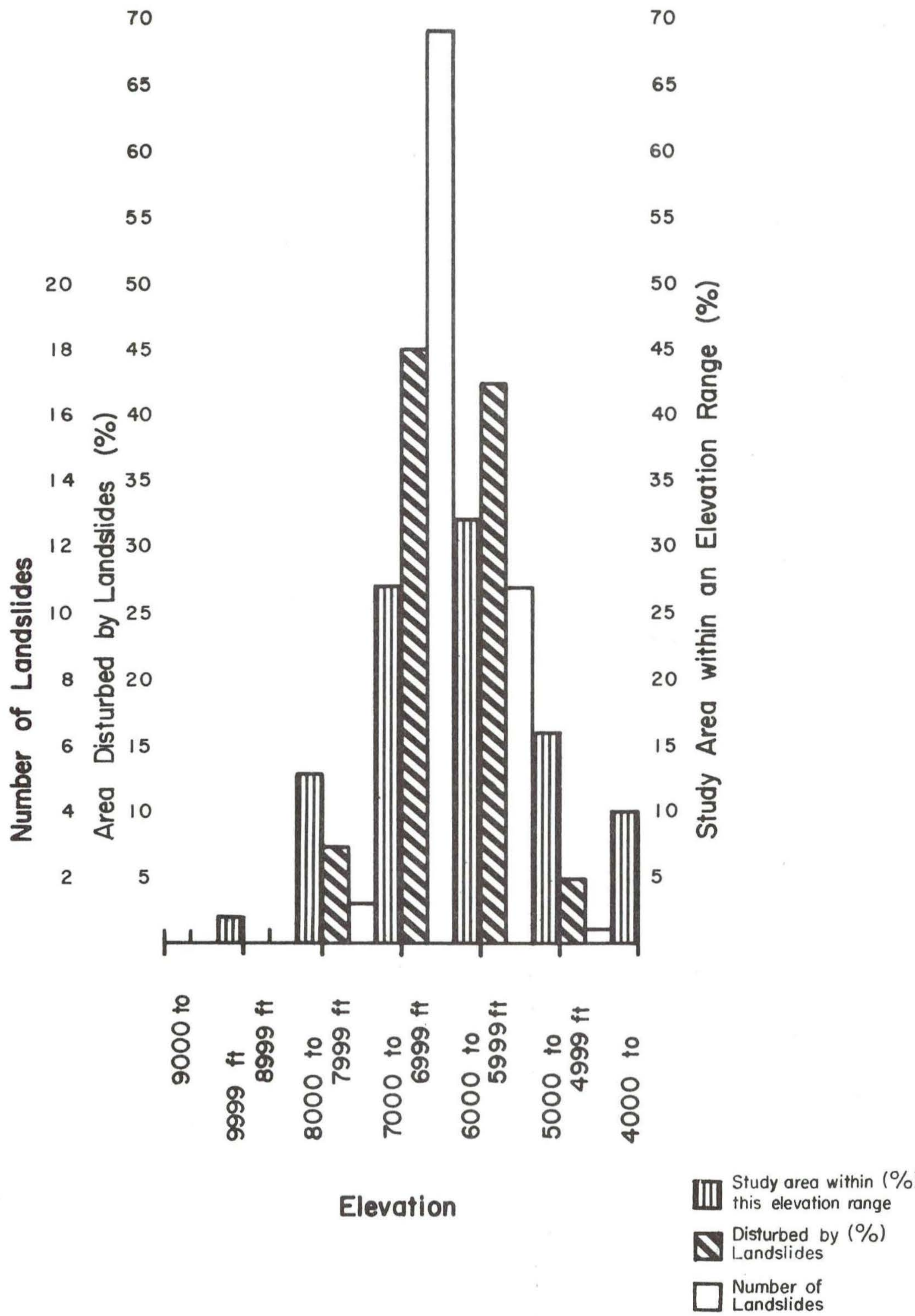

Figure 7. Graphic representation of landslides correlated with elevation zones.

percent. A graphic representation showing the number of landslides for each slope interval and the percentage of the total area involved shows that the highest number of landslides and the greatest amount of area disturbed are on slopes of twenty to twenty-four percent (Fig. 8). Within a plus or minus value of about eleven percent from the mean value, approximately sixty-eight percent of all landslides would be included. This amounts to roughly 76.6 percent of the total area disturbed by landslides.

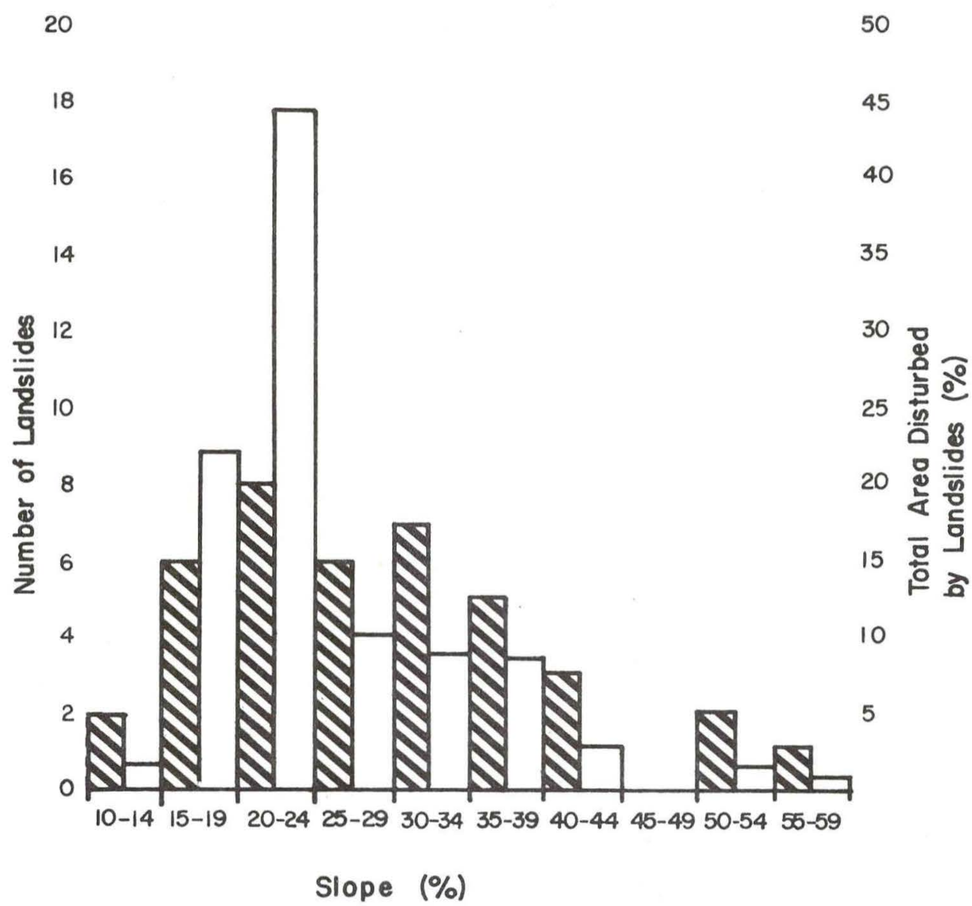

Figure 8. Graphic representation of landslides correlated with slope.

Alluvial Fans

Alluvial fans of varying sizes and ages have been mapped and examined in the six drainages of the Bear River Range: Green, Logan, Providence, Blacksmith Fork, Paradise Dry, and East canyons. The features have been identified based on the definition in the Glossary of Geology (1974):

> A low, outspread, relatively flat to gently sloping mass of loose rock material, shaped like an open fan or a segment of a cone, deposited by a stream (esp. in a semiarid region) at the place where it issues from a narrow mountain valley upon a plain or broad valley, or where a tributary stream is near or at its junction with the main stream, or whenever a constriction in a valley abruptly ceases or the gradient of the stream suddenly decreases; it is steepest near the mouth of the valley where its apex points upstream, and gradually decreasing gradient.

Tabulated of each fan are the area of the fan, area of its drainage, stream length, streamflow direction, highest elevation of the drainage, lowest elevation of the drainage, relef of the drainage, and gradient (Appendix 2). By means of a computer-processed statistical program, these data were analyzed for means, standard deviations, and stepwise deletion of independent and dependent variables. Investigations of alluvial fans in other parts of the country have related the fan size to the size of the drainage basin (Bull, 1964; Denny, 1965). An evaluation of this relationship and other influencing variables was attempted (Table 4). The same procedure was applied to only the fans that appear to have formed during the Hypsithermal (Table 5). In all cases, the correlation is tenuous at best. Low values for the coefficient of determination indicate that the linear regression best fitting the data points has no statistical validity.

The alluvial fans issue into the main canyon bottoms from smaller tributary canyons. All fans exhibit a typical radiating fan shape in plain view with the apex at the mouth of the tributary canyon. Most of the fans have little or no stratification, contain some large boulders or cobbles, but consist chiefly of gravel, sand, and silt-plus-clay. These factors suggest that the fans were deposited by mudflows or intermittent streams. The climatic

Table 4. Statistical Evaluation of Fan Area as a Dependent Variable Using All Alluvial Fan Values.*

Independent Variable	Corr. Coef.	Intercept	Slope	Coef. Deter.
Drainage Area	.47298	-5.0324	.4267	22.3%
Drainage Area x Gradient	.54013	0.2208	.5369	29.2%
Gradient	.02440	-0.9923	.0127	00.5%
Stream Length	.48312	9.8753	.2527	23.3%
Relief	.47110	8.8831	.2654	22.2%

* Both the dependent and independent variables are converted to natural log values before statistical model is applied.

Table 5. Statistical Evaluation of Fan Area as a Dependent Variable Using Hypsithermal Age Fan Values.*

Independent Variable	Corr. Coef.	Intercept	Slope	Coef. Deter.
Drainage Area	.57542	-4.5248	.5200	33.1%
Drainage Area x Gradient	.55954	0.5264	.5416	31.3%
Gradient	-.37300	-1.2304	-.9472	13.9%
Stream Length	.53979	9.9387	.2674	29.1%
Relief	.46053	8.7083	.1726	21.2%

conditions were probably arid to semiarid and characterized by scarce vegetative cover subject to periods of intense rainfall.

Alluvial fan formation appears to have taken place during a number of episodes (DeGraff, 1975a). The majority of alluvial fans found in Logan and Blacksmith Fork canyons formed during the Hypsithermal part of the Holocene Epoch. This time was characterized by semiarid conditions in this part of Utah (Williams, 1956). The fan formed under these conditions would be primarily the result of repeated mudflow deposition. A number of fans in Logan and Blacksmith Fork canyons were sampled. The composition of these fans is consistent with the suggested genesis under Hypsithermal climatic conditions (Tables 6 and 7). The main distinction between the fans in Logan Canyon and the fans in Blacksmith Fork Canyon is based on the mean values for gravel and sand. Fans in Logan Canyon have a higher percentage of sand. The percentage of silt-plus-sand is the same for fans in both canyons. Examination of fans in other drainages or in other parts of Logan and Blacksmith Fork canyons suggests that the relative composition of these fans is similar to those sampled.

Table 6. Composition and Character of Alluvial Fans of Hypsithermal Age in Logan Canyon

Fan	Mileage*	Gravel %	Sand %	Fines+ %	Strat.	Angularity	Cobbles#
1	3.6	68.3	25.5	6.2	poor	sub-angular	present
2	3.9	69.1	23.8	7.1	none	sub-angular	present
3	4.2	79.4	14.0	6.6	none	sub-angular	present
4	6.4	73.1	21.9	5.0	none	sub-angular	present
5	7.4	63.9	30.1	6.1	none	sub-angular	present
6	9.1	65.1	31.3	3.6	none	sub-angular	present
7	10.1	62.4	31.9	5.7	none	sub-angular	present
8	10.4	67.5	29.1	3.4	none	sub-angular	present
9	10.7	58.1	35.3	6.6	none	sub-angular	present
Mean values		67.4	27.0	5.6			

*Mileage values are east on U.S. Highway 89 from the corner of Main Street and 400 North in Logan, Utah.

#Also includes all sizes larger than cobbles.

+Includes silt and clay sizes.

Table 7. Composition and Character of Alluvial Fans of Hypsithermal Age in Blacksmith Fork Canyon

Fan	Mileage*	Gravel	Sand	Fines+	Strat.	Angularity	Cobbles#
1	2.4	69.5	22.2	8.3	none	sub-angular	present
2	3.2	71.3	24.4	4.3	none	sub-angular	present
3	4.3	62.0	33.1	4.9	none	sub-angular	present
4	4.8	75.5	21.1	3.3	none	sub-angular	present
5	5.1	67.2	22.1	10.7	poor	sub-angular	present
6	5.7	63.6	28.2	8.2	poor	sub-angular	present
7	6.7	71.8	21.2	6.9	none	sub-angular	present
8+	8.7	74.2	21.1	4.8	none	sub-angular	present
9	8.7	71.6	19.3	4.2	none	sub-angular	present
10	8.9	72.2	21.9	5.9	none	sub-angular	present
11	9.2	76.5	19.3	4.2	none	sub-angular	present
12+	9.2	79.0	18.8	2.2	none	sub-angular	present
13	9.7	72.3	24.8	2.9	none	sub-angular	present
14	10.1	72.9	22.7	3.4	poor	sub-angular	present
Mean values		71.5	23.2	5.3			

*Mileage values are east on Utah Highway 242 from the intersection of Utah Highways 101 and 242.

#Also includes all sizes larger than cobbles.

+These samples were collected from fan segments graded to a higher level than the segment of Hypsithermal Age located at the same site. It is inferred that the higher level is older than the lower segment at each particular site.

+Includes silt and clay sizes.

Patterned-Diamicton Fields

Four canyons contain localities with a beaded or striped pattern. On aerial photography, the appearance of these areas is similar to patterned ground associated with periglacial environments. The term, patterned ground, is defined in the American Geological Institute Glossary (1975) as:

> A group term suggested by Washburn (1950) for certain well-defined, more or less symmetrical forms, such as circles, polygons, nets, steps, and stripes, that are characteristic of, but not necessarily confined to, surficial material subject to intensive frost action.

Patterned-diamicton fields appear to most closely resemble either circles or stripes. Ground observations revealed that the patterned appearance involved only regolith at these sites. The pattern was much less apparent in ground-level observations. The mounds responsible for the pattern range from 13 to 66 feet across. The average mound diameter is 40 feet, and total relief is only 1 to 3 feet. The mounds are usually composed of sand, gravel, and cobbles. There is little difference in grain sizes between the mound and intermound areas. One site exhibits coarser material in the intermound area. This circumstance may result from flushing out of fine material from low intermound areas during spring runoff. The material both in and among the mounds appears to be derived from the same source at each site; but the parent material varies among different localities. These areas have been designated as patterned-diamicton fields of Quaternary age on Plate 1, in keeping with previous work in this region (Southard and Williams, 1970; Williams and Southard, 1970) (Fig. 9).

One area of patterned-diamicton is outside the confines of the canyons in the Bear River Range. This site is on McKenzie Flat, a pediment surface, just south of the mouth of East Canyon. This diamicton field is found within secs. 13, 14, 13, and 24, T. 9 N., R. 1 E., and on the Paradise 7.5-minute topographic map. Table 8 summarizes the physical dimensions of this diamicton field as site 1.

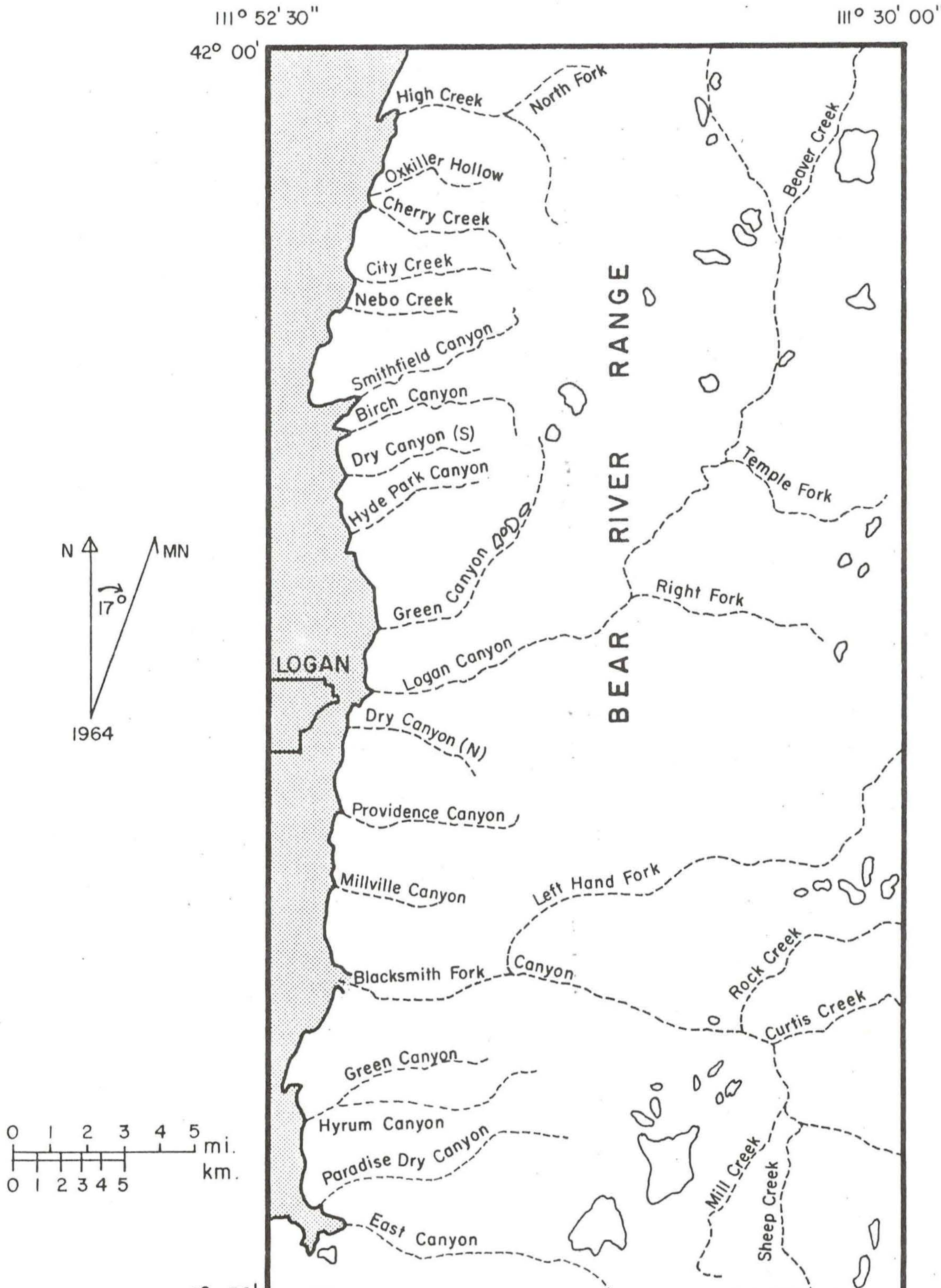

Figure 9. Map showing distribution of patterned-diamicton fields within the Bear River Range.

Table 8. Patterned-diamicton fields mapped in the Bear River Range.

Site	Upper Elev. (ft)	Lower Elev. (ft)	Slope (°)	Slope (%)	Aspect	Area Acres	Area Hectares
1	5,600	5,400	5	9	NW	204	83
2	9,200	8,400	23	42	SE	26	11
3	9,360	8,800	20	36	S	19	8
4	9,000	8,480	12	21	S	45	18
5	9,440	9,200	10	18	SE	26	11
6	9,160	8,360	22	40	S	51	21
7	8,560	8,440	4	7	SE	109	44
8	8,880	8,800	6	11	SE	6	2
9	8,080	8,000	4	7	SW	13	5
10	0,040	7,800	10	18	W	19	8
11	7,920	7,880	0	0	Horiz.	19	8
12	7,400	7,080	10	18	SW	58	23
13	8,320	7,840	14	25	SW	38	15
14	7,800	7,560	9	16	SW	58	23
15	6,200	6,160	5	9	W	19	8
16	6,600	6,480	4	7	SW	19	8
17	6,960	6,840	4	7	S	19	8
18	6,920	6,720	6	11	E	51	21
19	7,560	7,480	5	9	E	13	5
20	7,520	7,440	5	9	E	19	8
21	7,520	7,440	5	9	SW	13	5
22	7,120	7,000	4	7	W	134	54
23	7,120	7,040	5	9	NE	13	5
24	7,280	7,200	4	7	SW	32	13

Table 8. Patterned-diamicton fields mapped in the Bear River Range (Cont.).

Site	Upper Elev. (ft)	Lower Elev. (ft)	Slope (°)	Slope (%)	Aspect	Area Acres	Area Hectares
25	6,800	6,720	0	0	Horiz.	45	18
26	6,880	6,760	8	14	NW	32	13
27	7,000	6,880	17	31	W	32	13
28	6,640	6,560	6	11	NW	13	5
29	7,080	7,000	0	0	Horiz.	19	8
30	7,200	7,040	15	27	E	13	5
31	6,840	6,520	13	23	SW	70	28
32	7,160	7,040	0	0	Horiz.	45	18
33	7,080	6,920	0	0	Horiz.	371	150
34	8,600	8,480	9	16	SW	38	15
35	8,520	8,400	6	11	S	32	13
36	6,960	6,800	5	9	NW	19	8
37	7,080	6,840	7	12	W	32	13
38	7,200	6,840	10	18	W	38	15
39	7,688	7,400	0	0	Horiz.	346	140

The mounds are aligned in beaded stripes down the slope. The regolith was derived from the underlying Salt Lake Formation.

Green Canyon is the northernmost drainage basin. It contains patchy areas of patterned diamicton. Most of the diamicton sites are along the upper part of the canyon in the area adjacent to Mt. Jardine. The physical dimensions of sites two through five are summarized in Table 8.

The second site is on the south flank of Mt. Jardine, which forms the western slope of Green Canyon. This location is on the Mt. Elmer 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith probably was derived from the Madison Formation by nivation and weathering processes.

The third site is on the southeast flank of Mt. Jardine. This location is on the Mt. Elmer 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith probably was derived from the Madison Formation through nivation and weathering processes.

The fourth site is on the east flank of Mt. Jardine. This location is on the Mt. Elmer 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The patterned-diamicton occupies a probably nivation basin. The regolith involved was probably derived from the Madison Formation.

The fifth site is at the head of Green Canyon. This area is on the ridge just north of Mt. Jardine peak. This location is on the Mt. Elmer 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith probably was derived from the Madison Formation.

Logan Canyon contains areas with the patterned morphology. Most of the areas affected are in the upper reaches of the drainage basin. The physical dimensions of sites six through twenty-two are summarized in Table 8.

The sixth site is found at the head of Cottonwood Canyon, a tributary of

Logan Canyon, near the main ridge leading toward Naomi Peak to the north. This location is on the Naomi Peak 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the Laketown Formation which underlies the area.

The seventh site is found about 1.0 mile due north of Tony Grove Lake near the head of Bunchgrass Creek Canyon. This location is on the Naomi Peak 7.5-minute topographic map. The mounds are evenly distributed within the area. The regolith was probably derived from the underlying Garden City Formation.

The eighth site is found in the basin forming the head of Steam Mill Canyon. This location is on the Naomi Peak 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the underlying Garden City Formation.

The ninth site is found about 1.3 miles due north of Borden Reservoir and approximately 1.0 mile due east of Barrel Spring. This location is on the Temple Peak 7.5-minute topographic map. The mounds are evenly distributed. The regolith was derived from weathering of the conglomerate member of the Wasatch Formation.

The tenth site is found 0.5 mile northwest of the fourth site, 1.5 miles due south of Temple Spring, and approximately 2.5 miles due north of Trigaro Spring. This location is on the Temple Peak 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was derived from the conglomerate member of the Wasatch Formation.

The eleventh site is found 0.7 mile due north of Tin Cup Spring, 1.2 miles due south of the head of Log Cabin Hollow, and 7.3 miles due east of Logan Cave. This location is on the Temple Peak 7.5-minute topogrpahic mpa. The mounds are evenly distributed over the area. The regolith was probably derived from the Bloomington Formation.

The twelfth site is found near the 7,430-foot summit between Blind Hollow

and Bear Hollow. It is 1.7 miles north of the Twin Bridges picnic area in Logan Canyon. This location is on the Temple Peak 7.5-minute topographic map. The mounds are evenly distributed over this area. The regolith was probably derived from the Laketown Formation which underlies the site.

The thirteenth site is found 1.1 miles due south of Rex Reservoir, 2.3 miles due east of Lewis M. Turner Campground, and near the head of Little Bear Creek Canyon. This location is on the Tony Grove Creek 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the underlying Bloomington Formation.

The fourteenth site is found in White Pine Canyon. It is about 2.6 miles upstream from the junction of White Pine Creek and the Logan River. This location is on the Tony Grove Creek 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from glacial ground moraine composed of rock material from several formations which outcrop in the upper part of White Pine Canyon.

The fifteenth site is found just south of the Utah State University Forestry Field Station is Logan Canyon. It is adjacent to the Logan River at the mouth of the West Hodges Creek. This location is on the Temple Peak 7.5-minute topographic map. The mounds are evenly distributed over the area. The regolith was probably derived from glacial ground moraine and stream alluvium.

The sixteenth site is found near the junction of White Pine Creek and the Logan River. It is about 2.1 miles due north of the Utah State University Forestry Field Station. This location is on the Tony Grove Creek 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from both glacial ground moraine and stream alluvium.

The seventeenth site is found on the west slope of Logan Canyon about 2.7 miles due north of Lewis M. Turner Campground. This location is on the Tony Grove

Creek 7.5-minute topographic map. The mounds are evenly distributed over the area. The regolith was probably derived from both glacial ground moraine and steam alluvium.

The eighteenth site is found just north of the twelfth site. It is about 3.1 miles due north of Lewis M. Turner Campground. This location is on the Tony Grove Creek 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from both glacial ground moraine and stream alluvium.

The nineteenth site is must north of the junction of Crescent Lake Canyon and Logan Canyon. It is on the western slope of Logan Canyon. This location is on the Tony Grove Creek 7.5-minute topographic map. The mounds are evenly distributed over the area. The regolith was probably derived from both glacial ground moraine and stream alluvium.

The twentieth site is just north of the fourteenth site. It is approximately 1.1 miles due south of the intersection of the Logan River and the Utah-Idaho state line and on the west side of Logan Canyon. This location is on the Tony Grove Creek 7.5-minute topographic map. The mounds are evenly distributed over the area. The regolith was probably derived from glacial ground moraine and stream alluvium.

The twenty-first site is found just north of site fourteen on the east slope of Logan Canyon. It is about 0.5 mile south of the intersection of the Logan River and the Utah-Idaho state line. This location is on the Tony Grove Creek 7.5-minute topographic map. The mounds are evenly distributed over the are. The regolith was probably derived from glacial ground moraine and stream alluvium.

The twenty-second site is found at Beaver Basin. The western margin of this site is bisected by U.S. Highway 89. This location is on the Tony Grove Creek 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from alluvial material.

Blacksmith Fork Canyon, like Logan Canyon, has a large number of patterned-diamicton fields. Some of the largest sites are found in this drainage area. As in the other drainage basins, the patterned-diamicton fields are found in the upper reaches of the basin. The physical dimensions of the twenty-third through thirty-eighth sites are summarized in Table 8.

The twenty-third site is found at Bear Spring. It is about 3.6 miles east on Dip Hollow Road from the road junction with the Saddle Creek-Elk Valley Road. This location is on the Boulder Mountain 7.5-minute topographic map. The mounds are evenly distributed over the area. The regolith was derived from the Wasatch Formation.

The twenty-fourth site is found is sec. 21, T. 11 N., R. 4 E. at the junction of two small unimproved roads. This location is on the Boulder Mountain 7.5-minute topographic map. The mounds are evenly distributed over the flat area with some alignment into beaded stripes along the sloping margins. the regolith was probably derived from the Wasatch Formation.

The twenty-fifth site is found at Squaw Flats is secs. 29 and 20, T. 11 N., R. 4 E. This location is on the Boulder Mountain 7.5-minute topographic map. The mounds are evenly distributed over the flat area with some alignment into beaded stripes along the sloping margins. The regolith was probably derived from the Wasatch Formation.

The twenty-sixth site is found just west of Squaw Flats. The area is in sec. 25, T. 11 N., R. 3 E. and sec. 30, T. 11 N., R. 4 E. This location is on the Boulder Mountain 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the Wasatch Formation.

The twenty-seventh site is found just northeast of Squaw Flats along the west side of the Hardware Ranch-Danish Dugway Road. The area is in secs. 20 and 29,

T. 11 N., R. 4 E. This location is on the Boulder Mountain 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the Wasatch Formation.

The twenty-eighth site is found on the north side of Blacksmith Fork Canyon. The area is on a summit between Rock Creek and North Cottonwood Canyons in sec. 9, T. 10 N., R. 3 E. This location is on the Hardware Ranch 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the underlying Brigham Formation.

The twenty-ninth site is found on the 7,088-foot summit on the south side of Blacksmith Fork Canyon. It is in secs. 16 and 21, T 10 N., R. E. This location is on the Hardware Ranch 7.t-minute topographic map. The mounds are evenly distributed over the flat area. The regolith was probably derived from the underlying Brigham Formation.

The thirtieth site is found 0.6 mile southwest of the seventh site. This area is in sec. 20, T. 10 N., R. 3 E. The location is on the Hardware Ranch 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith is probably derived from the underlying Brigham Formation.

The thirty-first site is found 0.8 mile southeast of the seventh site. It is in sec. 21, T. 10 N., R. 3 E. This location is on the Hardware Ranch 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the underlying Brigham Formation.

The thirty-second site is found at the head of Curtis Hollow, a tributary to Mill Creek. It is in secs. 29 and 32, T. 10 N., R. 3 E. This location is on the Hardware Ranch 7.5-minute topographic map. The mounds are evenly distributed over the flat area. Some mounds are aligned in beaded stripes down the sloping margins. The regolith was probably derived from the Brigham Formation.

The thirty-third site is found at Bear Flat. Bear Flat is the area at the head of Fox and Bear Hollows, tribuaries of Mill Creek. This location is on the

Hardware Ranch and Procupine Reservoir 7.5-minute topographic maps. The mounds are evenly distributed over the areas, except for some beaded stripes down the sloping margins. The regolith was derived from the Wasatch Formation.

The thirty-fourth site is found 0.5 mile due west of Buck Spirng. It is in secs. 17 and 20, T. 9 N., R. 4 E. This location is on the Hardware Ranch 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the underlying Wasatch Formation.

The thirty-fifth site is found about 0.7 mile due north of Buck Spring and at the head of Petes Hollow. It is in sec. 17, T. 9 N., R. 4 E. This location is on the Hardware Ranch 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the Wasatch Formation underlying the area.

The thirty-sixth site is found 2.1 miles up South Cottonwood Canyon from its junction with Blacksmith Fork Canyon. It is in sec. 20 and 29, T, 10 N., R. 3 E. This location is on the Porcupine Reservoir 7.5-minute topograhic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the Brigham Formation.

The thirty-seventh site is found 3.0 miles up South Cottonwood Canyon from its junction with Blacksmith Fork Canyon. It is in sec. 29, T. 10 N., R. 3 E. This location is on the Porcupine Reservoir 7.5-minute topographic map. The regolith was probably derived from the underlying Brigham Formation.

The thirty-eighth site is found 3.2 miles up South Cottonwood Canyon from its junction with Blacksmith Fork Canyon. It is in secs. 29 and 32, T. 10 N., R. 3 E. This location is on the Porcupine Reservoir 7.5-minute topographic map. The mounds are aligned in beaded stripes down the slope. The regolith was probably derived from the Wasatch Formation.

The southernmost canyon containing patterned-diamicton fields is East

Canyon. The second largest site is located in this drainage basin. The physical dimensions of the thirty-ninth site are summarized in Table 8.

The thirty-ninth site is about 2.3 miles due south of Bear Flats and 3.7 miles due east of the eastern end of Porcupine Reservoir. This location is on the Porcupine Reservoir 7.5-minute topographic map. The mounds are evenly distributed over the flat part of the area. Some mounds are aligned in beaded stripes along the sloping margins. The regolith was probably derived from the Wasatch Formation.

The thirty-nine patterned-diamicton fields that have been identified and mapped (Fig. 9) occupy approximately 2,168 acres. Regolith at each site was derived from carbonates, quartzites, conglomerates, or unconsolidated material. Previous investigators noted the presence of a clay layer in the B horizon of the soil profile at depths of 2 to 4 feet at some patterned-diamicton sites (Williams and Southard, 1970; Southard and Williams, 1970). This clay layer was attributed to the tuffaceous Salt Lake Formation, from which the soil had been derived at those localities.

Locations of the sites are not restricted to specific physiographic settings. Diamicton fields are found through a wide range of elevations, on a variety of slope gradients, and oriented in every direction (aspect) except north.

The origin of these elements probably is frost heaving during the Pleistocene (DeGraff, 1975b). The factors of elevation, aspect, and solar insolation are balanced to produce approximately the same temperature ranges at all patterned-diamicton fields. The temperatures presently associated with patterned-diamicton fields are insufficient for active frost heaving.

Patterned-diamicton fields studied in the Bear River Range appear to be inactive. Erosion is currently modifying these fields. This conclusion is supported by present field observations and by a previous investigation (Southard and Williams, 1970). If frost heaving was responsible for the creation of the patterned-diamicton fields, it must have operated during a

cooler period than the present. Using the current temperatures and reconstructions of Pleistocene temperatures, it appears that conditions under the glacial episodes of the Pleistocene were the probable cause of these features. Some additional formation may have taken place during the Neoglacial (Williams. 1958b).

SITE LOCATION CONSIDERATIONS

Several factors should be considered in choosing sites for permanent facilities in the Logan Ranger District, Wasatch National Forest. These factors include slope stability, erosion, and aggregate resources.

Slope stability relates to mass movement and patterned-diamicton fields. A previous investigation of patterned-diamicton fields indicates that some long-term movement is associated with these features (Southard and Williams, 1970). In two instances, a thick clay horizon was found in the soil profile. Deformation evidenced along the clay horizon shows that some down-slope movement is taking place. The more obvious slope stability factors are mass movements. Analysis of landslides in the Bear River Range shows that few of these features are recent in age or currently active. While areas with active or recent landslides obviously should be avoided as sites, some inactive landslides may be locations to be avoided, too. The possibility of reactivation of movement exists in many cases. Site evaluation in areas without mapped landslides should examine the lithology, elevation, slope, and aspect of the location. Sites, with Tertiary age Salt Lake or Wasatch Formations as bedrock, have the highest probability of experiencing landsliding compared to other bedrock types. Landslide frequency is greatest in the elevation range between 6,000-6,999 feet. The elevation range between 5,000-5,999 feet is the elevation zone with the next highest probability of landsliding. Most landslides are found on slopes with low percentage grades. Over fifty percent of the mapped landslides are found on slopes with fourteen to twenty-nine percent grades. Slopes of twenty to twenty-four percent have the greatest probability of being subject to landsliding. Aspect is another factor controlling landslide occurrance. Slopes with a west or west-component aspect are most likely to have landsliding.

Slopes with a west aspect have the highest probability among these landslide-prone aspects. Clearly, a large part of the Logan Ranger District would be unsuitable for permanent facilites if every site was eliminated based on each of these factors. Choice of site should try to avoid as many of the high-probability factors as possible in relation to other restraints on site location.

Erosion potential will be determined by the constraints of slope, aspect, rock type, vegetative cover, and related factors. There is no evidence for mudslides or other active agents building alluvial fans within the study area. Most, if not all the fans, are Hypsithermal age or older. Serious dislocations in climate or vegetative cover would be required to re-activate fan formation. However, the location of fans provides some idea of the higher erosion areas. Approximately twice as many fans are found at the base of south-facing slopes. This indicator coupled with the observable vegetative cover difference suggests that higher erosion rates can be expected on south-facing slopes.

Aggregate resources are extremely limited within the Logan Ranger District. Alluvial fans are largely unstratified. Despite the high amount of gravel, the large amount of other gran sizes reduces efficient and economic recovery. This mixture of grain sizes is a direct result of alluvial fan genesis by mudflow deposition. The proximity of Lake Bonneville deposits in Cache Valley greatly reduces the necessity of alluvial fan deposits as a source of construction aggregate.

ERRATUM

The twenty-first feature is on the east side of Sheep Creek Valley about 1.4 miles south of the junction of Sheep Creek Valley and Petes Hollow. This site is adjacent to the south margin of feature twenty. This location is represented on the Hardware Ranch 7.5-minute topographic map. The feature is a debris-slip. The length-to-width ratio is +0.6. The material involved was drived by weathering from the Wasatch Formation. There is no evidence of current movement.

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Appendix I - Tabulation of Alluvial-Fan Measurements.

Fan	Upper Elev. (ft)	Lower Elev. (ft)	Relief (ft)	Length (mi)	Area (sq mi) Fan	Area (sq mi) Source	Flow Di-.
I. Green Canyon							
1	6,640	5,200	1,440	.53	.0014	.07	S
2	7,475	5,200	2,275	.77	.0059	.17	N
3	7,169	5,240	1,929	.79	.0036	.11	S
4	7,120	5,400	2,480	.69	.0036	.12	N
5	7,960	5,480	2,480	1.17	.0029	.38	S
II. Logan Canyon							
1	7,323	4,800	2,523	1.08	.0058	.38	N
2	7,000	4,840	2,160	.87	.0068	.13	S
3	7,360	4,880	2,480	.94	.0064	.18	S
4	8,720	4,880	3,840	1.65	.0035	.86	N
5	7,475	4,960	2,515	1.20	.0060	.29	S
6	7,320	5,000	2,320	.76	.0136	.74	S
7	7,000	5,000	2,000	.60	.0037	.06	N
8	7,680	5,000	2,680	.80	.0064	.10	N
9	8,000	5,000	3,000	.94	.0071	.08	N
10	8,253	5,000	3,253	1.05	.0129	.21	N
11	6,400	5,040	1,360	.44	.0017	.04	S
12	6,960	5,040	1,920	.57	.0013	.07	S
13	7,800	5,080	2,720	1.20	.0121	.51	S
14	7,600	5,040	2,560	1.14	.0043	.16	N
15	8,914	5,120	3,794	2.32	.0133	1.57	S
16	8,573	5,120	3,453	1.38	.0038	.42	S

Appendix I - Tabluation of Alluvial-Fan Measurements (Cont.).

Fan	Upper Elev. (ft)	Lower Elev. (ft)	Relief (ft)	Length (mi)	Area Fan (sq mi)	Area Source (sq mi)	Flow Di..
II. Logan Canyon (Cont.)							
17	8,000	5,120	2,880	1.26	.0045	.35	N
18	8,320	5,120	3,200	1.37	.0060	.46	N
19	7,200	5,120	2,080	.65	.0010	.09	S
20	6,120	5,120	1,000	.29	.0003	.02	S
21	8,040	5,160	2,880	1.15	.0023	.22	S
22	7,200	5,160	2,040	.83	.0041	.17	N
23	6,583	5,160	1,423	.54	.0019	.09	S
24	8,400	5,160	3,240	1.36	.0073	.33	S
25	7,600	5,200	2,400	1.02	.0026	.15	S
26	6,760	5,200	1,560	.68	.0106	.12	N
27	8,400	5,200	3,200	1.58	.0041	.48	S
28	8,914	5,280	3,634	2.77	.0028	2.49	S
29	7,522	5,200	2,322	.95	.0024	.21	N
30	9,065	5,320	3,745	2.89	.0037	3.98	S
31	6,920	5,560	1,360	3.20	.0017	2.30	N
32	8,560	6,760	1,800	.91	.0009	.15	S
33	8,560	6,800	1,760	.75	.0004	.07	S
34	8,800	6,840	1,960	1.02	.0004	.24	S
35	8,800	6,840	1,960	.95	.0004	.19	S
35	9,161	7,040	2,121	2.10	.2596	.56	W
III. Providence Canyon							
1	6,760	5,560	1,200	.39	.0057	.04	N

Appendix I - Tabulation of Alluvial-Fan Measurements (Cont.).

Fan	Upper Elev. (ft)	Lower Elev. (ft)	Relief (ft)	Length (mi)	Area Fan (sq mi)	Area Source (sq mi)	Flow Dir.
III. Providence Canyon (Cont.)							
2	7,760	5,640	2,120	.96	.0071	.20	S
3	8,800	5,920	2,880	1.06	.0056	.24	N
4	7,280	6,160	1,120	.29	.0046	.01	N
IV. Blacksmith Fork - Main Canoy							
1	8,184	4,880	3,304	1.37	.0033	.46	S
2	7,640	4,920	2,720	.90	.0026	.19	S
3	7,838	4,880	2,958	1.22	.0028	.34	N
4	7,200	4,880	2,320	.82	.0037	.11	N
5	8,800	4,920	3,880	1.34	.0009	.48	S
6	7,840	5,000	2,840	1.06	.0063	.24	N
7	8,106	5,000	3,106	1.50	.0140	.75	N
8	8,455	5,000	3,455	1.15	.0025	.22	S
9	8,116	5,000	3,116	1.06	.0044	.14	N
10	8,080	5,000	3,080	1.13	.0090	.21	S
11	8,000	5,040	2.960	.96	.0111	.18	S
12	8,200	5,040	3,160	1.50	.0145	.61	N
13	7,600	5,040	2,560	.81	.0055	.09	S
14	6,400	5,040	1,360	.39	.0024	.04	S
15	7,560	5,080	2,480	.79	.0050	.11	S
16	8,258	5,080	3,178	1.89	.0042	.65	N
17	7,040	5,160	1,880	.62	.0023	.10	S
18	7,133	5,080	2,053	.77	.0103	.15	S

Appendix I - Tabulation of Alluvial-Fan Measurements (Cont.).

Fan	Upper Elev. (ft)	Lower Elev. (ft)	Relief (ft)	Length (mi)	Area Fan (sq mi)	Area Source (sq mi)	Flow Dir.
IV. Blacksmith Fork - Main Canyon (Cont.)							
19	7,040	5,080	1,960	.66	.0039	.10	S
20	6,360	5,080	1,280	.52	.0036	.07	S
21	7,480	5,120	2,360	1.02	.0015	.19	N
22	6,000	5,120	880	.28	.0009	.01	S
23	7,576	5,120	2,456	1.19	.0134	.33	S
24	6,400	5,160	1,240	.54	.0019	.05	S
25	7,680	5,160	2,520	1.04	.0060	.37	N
26	7,040	5,200	1,840	.77	.0025	.10	S
27	7,680	5,200	2,480	.94	.0064	.28	N
28	7,576	5,200	2,376	1.00	.0049	.20	S
29	7,586	5,240	2,346	1.20	.0160	.52	S
30	7,136	5,240	1,896	.81	.0181	.15	S
31	6,040	5,240	800	.24	.0011	.01	S
32	7,480	5,280	2,200	1.69	.0033	.45	S
33	7,920	5,280	2,640	2.07	.0151	.61	N
34	7,000	5,240	1,760	1.67	.0223	.55	S
35	7,800	5,280	2,520	2.31	.0270	.99	N
36	6,760	5,280	1,480	.63	.0017	.09	S
37	6,720	5,280	1,440	.62	.0077	.10	S
38	6,600	5,280	1,320	.50	.0020	.04	S
39	6,840	5,320	1,520	.65	.0033	.12	S
40	6,200	5,320	880	.36	.0018	.03	S

Appendix I - Tabulation of Alluvial-Fan Measurements (Cont.).

Fan	Upper Elev. (ft)	Lower Elev. (ft)	Relief (ft)	Length (mi)	Area (sq mi) Fan	Area (sq mi) Source	Flow Dir.
IV. Blacksmith Fork - Main Canyon (Cont.)							
41	6,840	5,320	1,520	2.78	.0033	2.41	S
42	6,480	5,400	1,080	.48	.0052	.05	S
43	6,600	5,400	1,120	.68	.0136	.20	S
44	7,000	5,400	1,600	1.11	.0012	.47	N
45	6,240	5,440	800	.30	.0003	.02	S
46	6,720	5,480	1,240	.65	.0018	.11	S
47	6,600	5,480	1,120	.58	.0076	.08	N
48	6,600	5,520	1,080	.95	.0086	.21	N
49	6,080	5,520	560	1.56	.0073	.64	S
50	5,680	5,520	160	.69	.0049	.19	S
51	6,360	5,600	760	1.05	.0336	.28	N
52	7,088	5,560	1,528	2.25	.0033	.95	E
53	6,320	6,600	720	.50	.0007	.04	W
54	6,320	5,600	720	.58	.0005	.06	W
55	6,440	5,640	800	1.24	.0017	.33	W
56	6,440	5,640	800	1.22	.0019	.28	W
57	6,440	5,640	800	.81	.0010	.12	W
58	6,640	5,800	840	1.53	.0011	.57	S
59	6,680	6,120	560	.52	.0015	.07	S
60	8,135	6,240	1,892	.88	.0032	.19	N
61	6,800	5,960	840	.76	.0008	.12	S
62	7,760	6,000	1,760	.84	.0038	.17	S

Appendix I - Tabluation of Alluvial-Fan Measurements (Cont.).

Fan	Upper Elev. (ft)	Lower Elev. (ft)	Relief (ft)	Length (mi)	Area Fan (sq mi)	Source	Flow Dir.
IV. Blacksmith Fork - Main Canyon (Cont.)							
63	7,760	6,040	1,720	.76	.0060	.07	S
64	7,000	5,960	1,040	.97	.0036	.16	W
65	7,000	6,040	960	.97	.0022	.38	W
66	7,400	6,080	1,320	1.47	.0044	.55	W
67	6,468	6,080	388	.42	.0020	.07	E
68	7,338	6,120	1,218	1.03	.0041	.16	W
69	6,642	6,160	482	.48	.0010	.05	E
70	6,338	6,200	1,138	.99	.0027	.29	W
71	8,000	6,560	1,440	1.46	.0014	.47	S
72	6,253	5,800	453	.41	.0014	.04	W
73	6,240	5,800	440	.40	.0008	.04	W
74	6,280	5,840	440	.40	.0005	.04	W
75	7,080	5,840	1,240	2.64	.0032	1.16	E
76	7,000	5,840	1,160	2.53	.0012	1.21	E
77	6,240	5,960	280	.47	.0009	.07	W
78	6,800	6,000	800	.90	.0009	.14	E
79	6,480	6,040	440	.41	.0014	.08	W
80	6,640	6,280	360	.57	.0016	.14	W
81	6,640	6,320	320	.54	.0004	.10	W
82	6,720	6,320	400	.82	.0014	.22	W
V. Blacksmith Fork - Left Hand Fork							
1	8,520	5,200	3,320	1.10	.0089	.15	S

Appendix I - Tabluation of Alluvial-Fan Measurements (Cont.)

Fan	Upper Elev. (ft)	Lower Elev. (ft)	Relief (ft)	Length (mi)	Area Fan (sq mi)	Area Source (sq mi)	Flow Dir.
V.	Blacksmith Fork - Left Hand Fork (Cont.)						
2	8,600	5,240	3,360	1.14	.0073	.32	S
3	8,720	5,280	3,440	1.34	.0042	.30	S
4	7,544	5,320	2,224	1.08	.0077	.45	N
5	6,840	5,320	1,520	.67	.0010	.08	S
6	8,800	5,400	3,400	1.83	.0040	1.66	S
7	7,280	5,400	1,880	.76	.0034	.10	S
8	7,544	5,440	2,104	.75	.0027	.14	N
9	7,360	5,440	1,920	.82	.0069	.14	S
10	6,320	5,480	840	.26	.0009	.02	S
11	7,160	5,480	1,680	.49	.0023	.07	N
12	6,920	5,480	1,440	.43	.0008	.03	S
13	7,000	5,480	1,520	.45	.0009	.04	S
14	7,120	5,480	1,640	.44	.0032	.04	N
15	7,200	5,520	1,680	.58	.0026	.08	N
16	7,200	5,560	1,640	.49	.0026	.04	N
17	6,760	5,560	1,200	.39	.0031	.04	N
18	7,000	5,560	1,440	1.03	.0045	.20	N
19	6,600	5,560	1,040	.33	.0010	.02	N
20	7,040	5,760	1,280	.45	.0005	.05	N
21	7,040	5,800	1,240	.50	.0005	.08	S
22	7,480	5,800	1,680	.88	.0014	.14	S
23	7,040	5,800	1,240	1.23	.0014	.64	N

Appendix I - Tabulation of Alluvial-Fan Measurements (Cont.).

Fan	Upper Elev. (ft)	Lower Elev. (ft)	Relief (ft)	Length (mi)	Area (sq mi) Fan	Area (sq mi) Source	Flow Dir.
V. Blacksmith Fork - Left Hand Fork (Cont.)							
24	7,200	5,800	1,400	.57	.0004	.10	S
25	7,480	5,840	1,640	1.78	.0011	.59	S
26	7,120	5,880	1,240	.37	.0006	.04	S
27	7,440	5,880	1,560	1.49	.0017	.55	S
28	7,400	5,960	1,440	1.76	.0037	.63	S
29	7,440	6,400	1,040	2.22	.0034	1.87	S
30	7,525	6,440	1,085	.96	.0074	.20	S
VI. Paradise Dry Canyon							
1	5,800	5,280	520	.58	.0021	.05	S
2	5,960	5,280	680	.64	.0015	.05	S
3	5,840	5,320	520	.43	.0008	.03	S
4	7,480	5,320	2,160	1.32	.0034	.36	S
5	6,920	5,360	1,560	.68	.0009	.05	S
6	7,113	5,520	1,593	.64	.0050	.10	S
7	7,680	5,600	2,080	1.00	.0030	.16	S
VII. East Canyon							
1	7,147	5,080	2,067	2.05	.0071	.70	S
2	6,600	5,120	1,480	.81	.0063	.13	N
3	6,840	5,200	1,640	1.51	.0071	.51	S
4	6,240	5,400	840	.41	.0017	.04	S
5	6,400	5,400	1,000	.49	.0036	.03	S
6	7,000	5,400	1,600	.72	.0046	.09	S

Appendix I - Tabulation of Alluvial-Fan Measurements (Cont.).

Fan	Upper Elev. (ft)	Lower Elev. (ft)	Relief (ft)	Length (mi)	Area Fan (sq mi)	Area Source (sq mi)	Flow Dir.
VII. East Canyon (Cont.)							
7	5,880	5,400	480	.21	.0004	.01	S
8	7,240	5,440	1,800	.72	.0016	.14	S
9	7,600	5,440	2,160	.84	.0030	.14	N
10	6,440	5,440	1,000	.34	.0007	.03	S
11	8,480	5,480	3,000	1.97	.0123	1.26	S
12	6,640	5,480	1,160	.52	.0028	.06	S
13	6,160	5,480	680	.35	.0016	.02	S
14	8,211	5,520	2,691	1.09	.0049	.21	S
15	6,680	5,560	1,120	.50	.0007	.05	S
16	8,240	5,640	2,600	1,88	.0256	.74	S
17	7,600	5,600	2,000	1.11	.0022	.35	N
18	8,040	5,640	2,400	1.49	.0050	.61	S

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1914

INVENTORY OF PLEISTOCENE-HOLOCENE DEPOSITS

LEGEND

Patterned Ground

Landslide

F Alluvial Fan

LS

PLATE 1